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Atmospheric Structure Satellite
Explorer XVII (S-6)

J. N. Libby and J. C. Schaffert
Space Technology Division, GSFC

August 1963

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

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PROGRAMMER ELECTRONICS

Atmospheric Structure Satellite
Explorer XVII (S-6)

by

J.N. Libby and J.C. Schaffert
Space Technology Division, GSFC

I. INTRODUCTION

On April 2, 1963, Explorer XVII (S-6) (Figure 1) was launched successfully into an eccentric orbit extending from a perigee of 225 km to a minimum apogee of 917 km. The orbit has an equatorial inclination of 57.63 degrees with an orbital period of 96.4 minutes. The Delta (DVS-3B) vehicle (Figure 2) was launched in a vertical position from Complex 17 at the Atlantic Missile Range, Cape Canaveral, Florida, with a range heading of approximately 49 degrees.

The S-6 spacecraft (Figure 3) is a vacuum-tight spherical payload weighing approximately 400 pounds with an outer shell diameter of approximately 35 inches. With its thermal coating in place, the spacecraft is expected to have an optical reflectivity of 70 to 90 percent and a radar cross section of 6.7 square feet. At an altitude of 500 miles and in optimum sunlight, the spacecraft should appear as a star of the eighth magnitude.*

The S-6 spacecraft has a 25-mw CW tracking beacon continuously transmitting on 136.560 Mc, and a 500-mw PCM/PSK/NRZ/PM telemetry transmitter on 136.320 Mc which will transmit for a period of approximately 280 seconds upon command. Battery power restrictions limit the beacon life to an expected 3 months and the telemetry transmitter life to approximately 750 command responses.

The general mission of the Atmospheric Structure Satellite (S-6) is to investigate various aspects of atmospheric structure. Its primary purpose is to measure the density, composition, vertical particle temperature, and electron temperature of the earth's atmosphere from 250 to 900 kilometers, and to determine the variation of these parameters with time of day, latitude, and season.

*See X-533-63-29.

Figure 1-Artist's Conception, S-6 Satellite

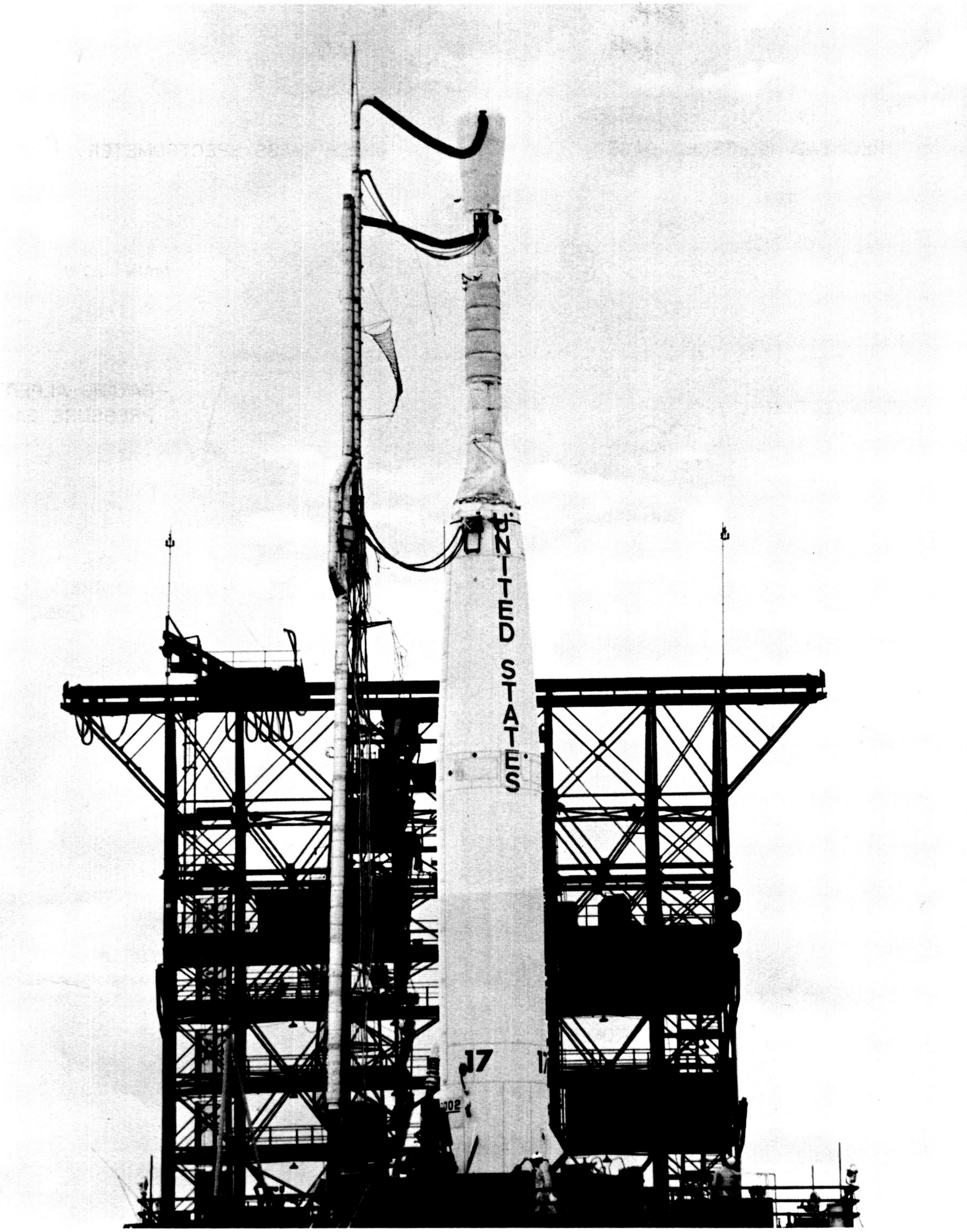


Figure 2-Delta Launch Vehicle

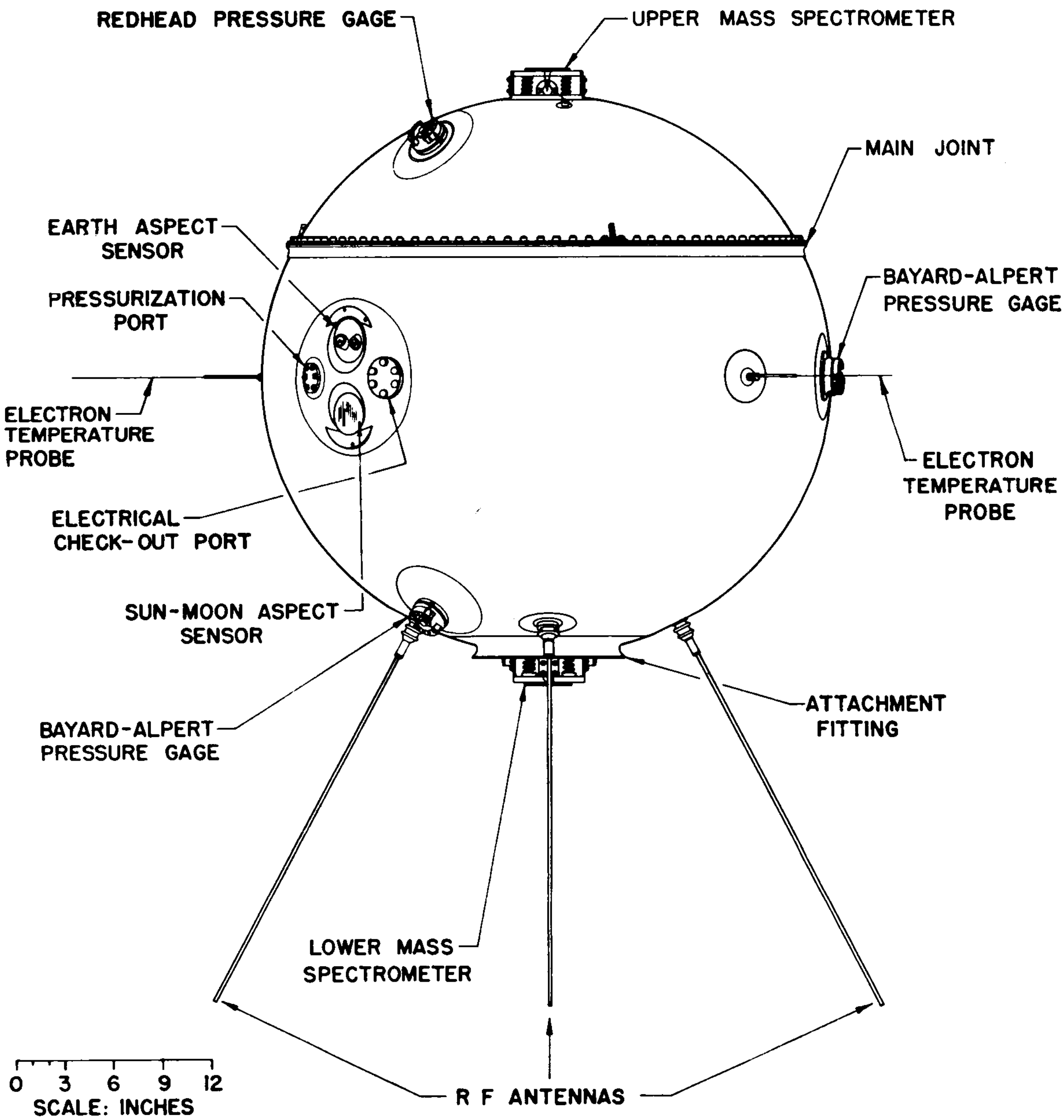


Figure 3-S-6 Atmospheric Structure Satellite

II. PURPOSE

This report describes the instrumentation provided for S-6 by the Programmers Section (Code 632.5) of the Flight RF Systems Branch, Spacecraft Technology Division. Figure 4 is a partial cutaway view of the satellite showing the instrumentation layout. Figure 5 is a spacecraft block diagram showing in heavy outline the blocks for which the Programmers Section is responsible:

- Programmer - 4A
- Experiment selector switch (ESS)-4C
- Programmer card - 4B
- Experiment selector switch card — 4D
- Silicon controlled rectifiers (SCR)-18B
- MS1 and MS2 calibrators - 5A04 and 6A04.

This report therefore considers the philosophy and operation of the program system as well as the circuit description for these and other functions of the contributed hardware.

III. COMMAND PROGRAMMER SYSTEM

The S-6 spacecraft employs a telemetry command system which enables payload turn-on and experiment selection. Turn-off is automatic either by completion of a 5-minute program or by a back-up 7-minute timer. This redundancy is incorporated to make certain that useless battery drain does not occur as a result of operator errors or of the spacecraft passing out of command-range capability.

Spacecraft command electronics includes the telemetry antenna, a frequency-selective hybrid for beacon-frequency rejection, two command receivers each capable of responding to two of the three command tones, and the associated command control circuitry. For redundance, both receivers respond to command tone A, one responds to B, and the other to C, where A = 3000 cycles, B = 2500 cycles and C = 3745 cycles.

Referring to Figure 6, command tone A from the ground-station command transmitter is detected by command receivers A and B. Output A1 or B1 energizes the spacecraft program and telemetry system to the ON mode. This command must be maintained for approximately 2 seconds to start the programmer for its format of 280 seconds. Command B is detected by Receiver A, and the output A2 is used to step the experiment-selector switch one step clockwise for each command pulse; Command C

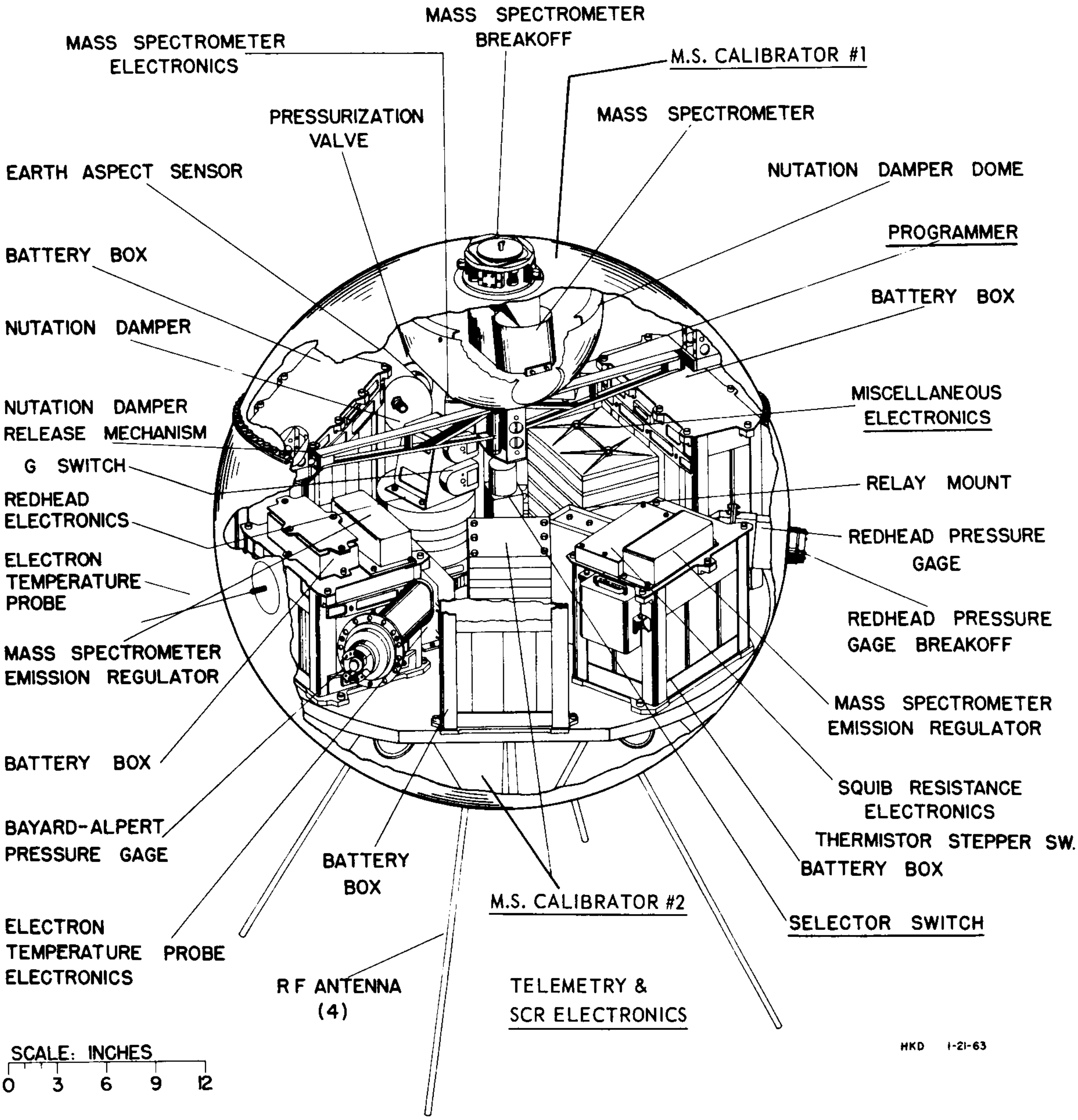


Figure 4–Cutaway View, S-6 Satellite

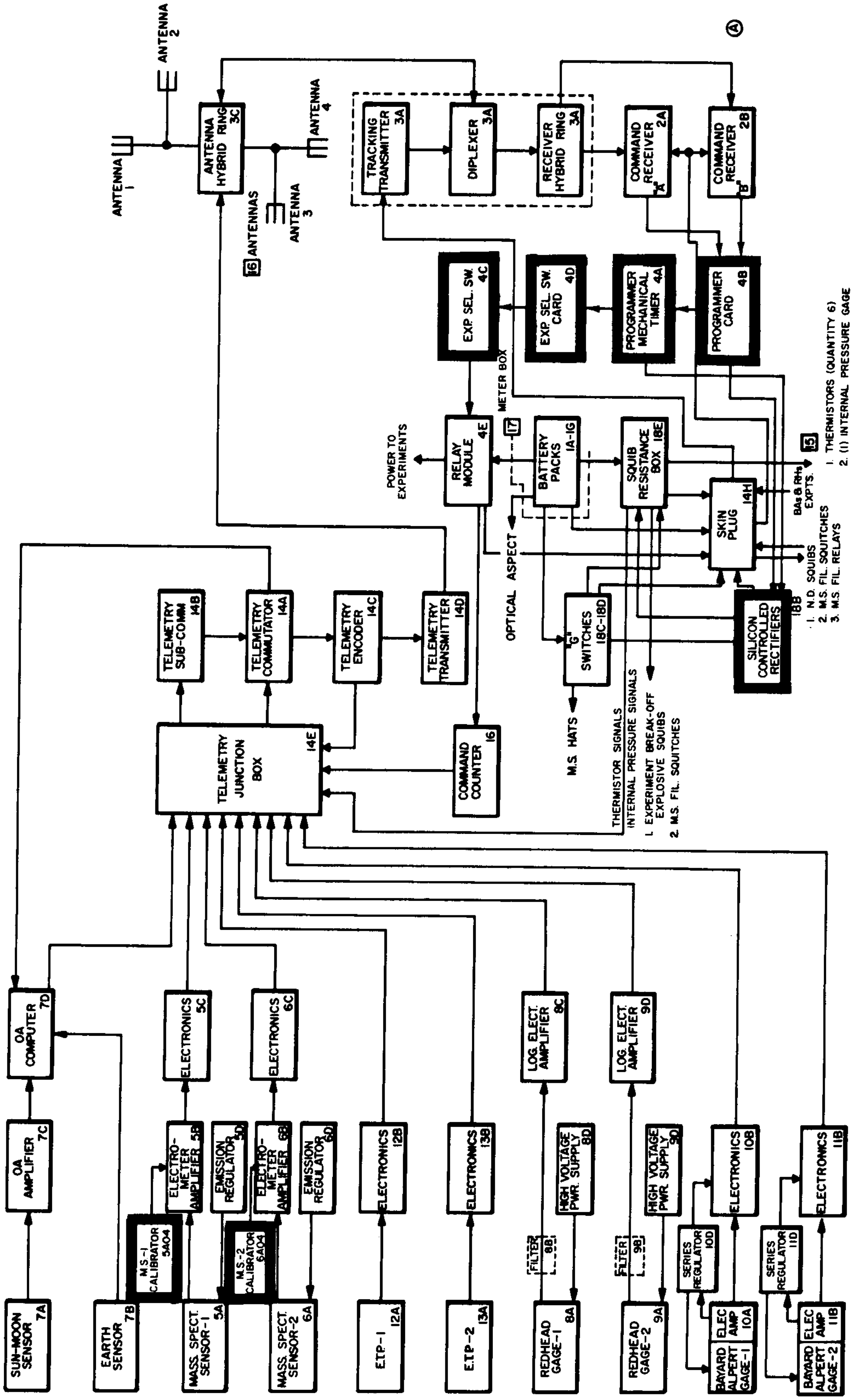


Figure 5-Spacecraft Block Diagram

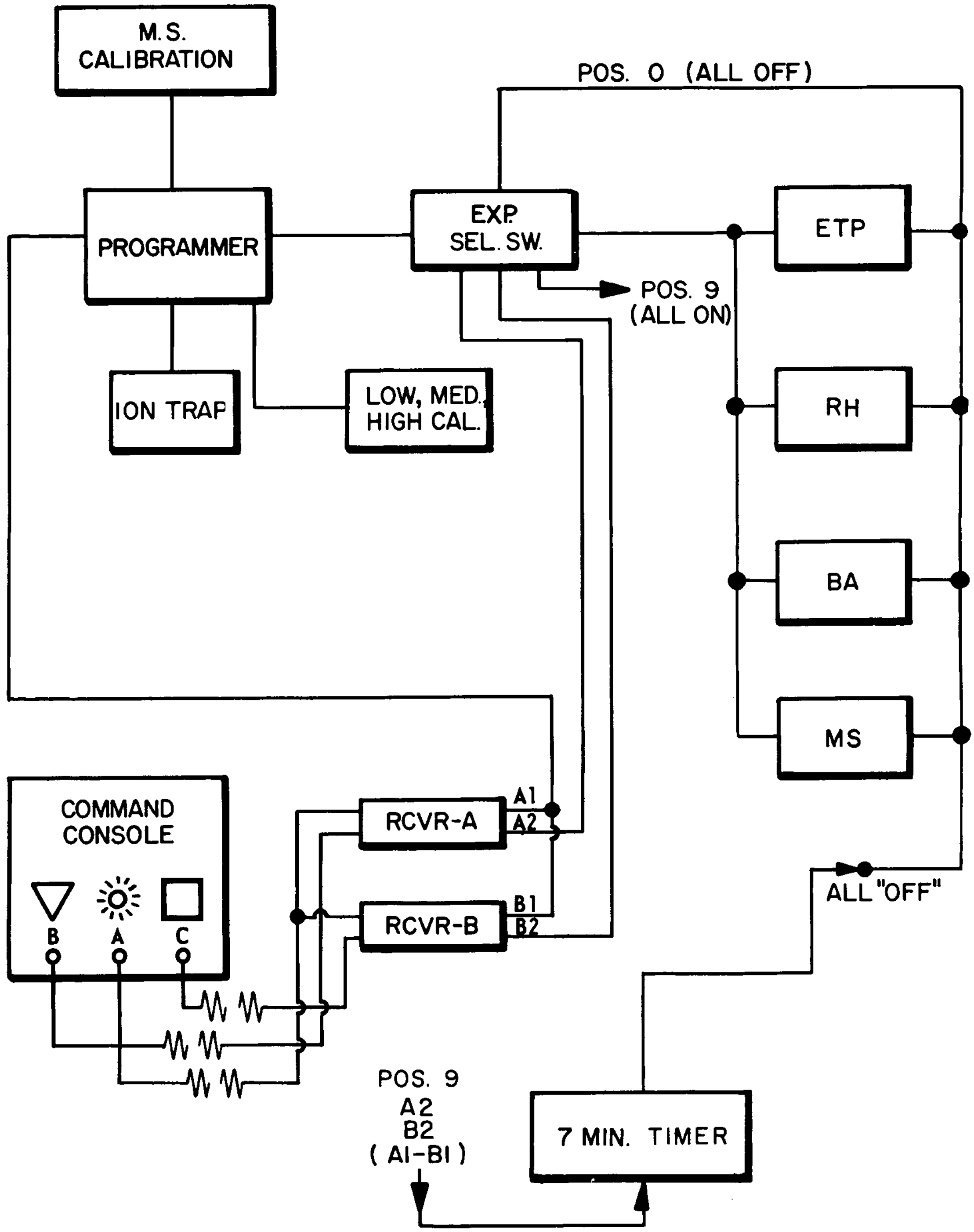


Figure 6-Command Program Function, Block Diagram

is detected by Receiver B, and the output B2 is used to step the experiment-selector switch one step counter-clockwise for each command pulse. Commands B and C have low-frequency noise filters and actuation delays which require a 4-second delay between successive pulses to assure actuation. Redundancy is obtained by using an output from each receiver to start the program and by having two outputs available for stepping the experiment-selector switch. It should be pointed out that, with all commands, the 7-minute timer is always started. This clock provides two functions:

(1) Turns OFF all experiments and telemetry that had been turned ON by the programmer, in case the programmer fails to complete its cycle

(2) Turns OFF all experiments and telemetry that had been turned ON by command position 9 (manual ON) of the experiment-selector switch, in case the operator fails to turn OFF manually (position 0) before the payload escapes telemetry range

The timer therefore is initiated by every command signal (A, B, and C) and provides a turn-off pulse 7 minutes later which will turn OFF everything that was turned ON because of either programmer failure or failure to command position 0 of the experiment selector switch.

A. Program Sequence

The programmer runs for a total of 280 seconds and is subcommutated in the following sequence:

ON (sec)	OFF (sec)	Function
0	280	Telemetry and programmer
0	30	Time select
30	280	All selected experiments
120	190	Ion trap turn-on
130	135	BA-RH high calibrate
135	140	RH medium calibrate
140	150	BA-RH low calibrate
0	420	7-minute timer

Every time the programmer is turned on (command A), the above sequence occurs with the exception of T = 30 seconds. At this time, only the experiment or experiments selected by the operator will be turned on. The selection is made during the time-select bracket (0 - 30 seconds) by transmission of command B or C.

In the case of command B, the experiment selector switch will step one position forward, or clockwise; in the case of command C, the switch will step one position backwards, or counter-clockwise.

It is seen that at command A time (or T = 0) the programmer, telemetry, and 7-minute timer are turned on. From T = 0 to T = 30, the experiment selector can be changed. At T = 30, these selected experiments are turned ON.

B. Experiment-Selector Switch (ESS)

The purpose of the ESS is to enable determination of possible interference between simultaneously operated experiments and to enable possible emphasis of particular measurements. The format for the experiment selector switch is:

Switch Position	Experiment Energized
1	Bayard-Alpert gauge (BA)
2	Mass spectrometer (MS)
3	Redhead gauge (RH)
4	Electron-temperature probe (ETP)
5	BA+MS+RH+ETP
6	BA+MS+ETP
7	MS+RH+ETP
8	BA+RH+ETP
9	Emergency manual "ALL ON"
0	Emergency manual "ALL OFF"

The ESS is essentially in series with the 5-minute programmer. Experiments selected by positions 1 through 8 will be turned on at T = 30 seconds of the programmer.

These experiment combinations allow for resolution of possible interference between the various sensors. It should be noted, however, that any possibility of interference between the electron-temperature probe and the various sensors appears to be very remote; therefore, the electron-temperature probes will be "ON" with all possible experiment combinations, i.e. experiment-selector switch positions 5 through 8. The operator has from 0 to 30 seconds (time-select time) to make his selection after the programmer command A; at the end of this time-select gate, he loses command capability (for that pass) and the programmer will turn ON only the experiments associated with the switch position effected during the initial 30 seconds. The ESS position may be changed after this time, but the program will not change to the new selection until the next main command of the programmer.

The step position of the ESS is transmitted by the telemetry to the ground station. If the operator changes the selection of the ESS position prior to a command program, he will have to estimate the position of the ESS, as there will be no telemetry signal to indicate position at this time.

Positions 9 and 0 of the ESS are emergency functions only, to be used in case of programmer failure. Position 9 turns "ON" all the experiments. Subcommutated times of the programmer, of course, will not be transmitted, as the programmer is bypassed; therefore, the ion trap, BA low- and high-calibrate, RH low-, medium-, and high-calibrate, and the MS calibrators are not turned ON in this emergency position. Telemetry, of course, is turned ON by position 9. Position 0 turns OFF everything that had been turned ON by position 9.

A 2-second delay is necessary between command steps to allow for recovery of the electronic circuitry.

C. Calibrators

Sequential voltage calibrators are provided for the upper and lower mass spectrometers. The calibrators switch into the mass-spectrometer electrometer feedback loop, seven calibrated voltages of 2 seconds duration each. This staircase voltage commences when coincidence is achieved between the start of cam 6 of the command programmer (120 - 190 seconds) and the trailing edge of the MS sample time (leading edge of L0 re-zero) of the mass spectrometer timing cycle (176 seconds). At this coincidence time, the calibration voltages are switched across a 20K ohm load in the feedback loop of the electrometer amplifier; at the same time, the mass-spectrometer logic is interrupted for the 14-second duration of the calibration. At the end of this calibrate time, switching occurs, allowing the mass-spectrometer time logic to start its normal function again.

Calibrated voltage outputs of the two sequence voltage calibrators into their respective loads (installed in the electrometer unit) are:

Time (sec)	Output (volts)
0 - 2	0 (GND)
2 - 4	.01
4 - 6	.03
6 - 8	.1
8 - 10	.3
10 - 12	1.0
12 - 14	10.0

The circuit also includes a flag to telemetry which identifies the calibration time, allowing the ground computer to immediately process these calibrations.

D. Squib Circuitry

Squib circuitry is provided for the following functions:

- Release of mass spectrometer breakoff hats
- Release of nutation damper
- Release of BA hats
- Release of RH hats
- Actuation of MS squitches

Referring of Figure 7, with the enable-disable relay in the position shown, the G-switch starts its timing cycle at launch. The G-switch closes 1800 seconds later, energizing the squibs for the nutation damper and mass spectrometer breakoffs through the contacts of relay RL1. Closing the G-switch also "arms" the SCR circuits so that when the programmer cycle is commanded, cams 6, 9, and 10 or the output of the 7-minute timer will trigger the SCR's; this in turn applies voltage to the squibs, releasing the BA hats, and RH hats and firing the mass-spectrometer squitches.

The enable position is provided, at launch, by placing the experiment-selector switch in position 0 and commanding ON the programmer. This command closes RL2 for 10 seconds (obtained from position 0) placing 20.15 volts on the enable coil of RL1 (the configuration is as shown in the drawing). However, once airborne, voltages to the squibs after actuation must be turned off or opened; the disable circuit will do this by advancing the experiment selector switch to position 9 so that, when commanded, the programmer energizes RL2. The relay contacts close,

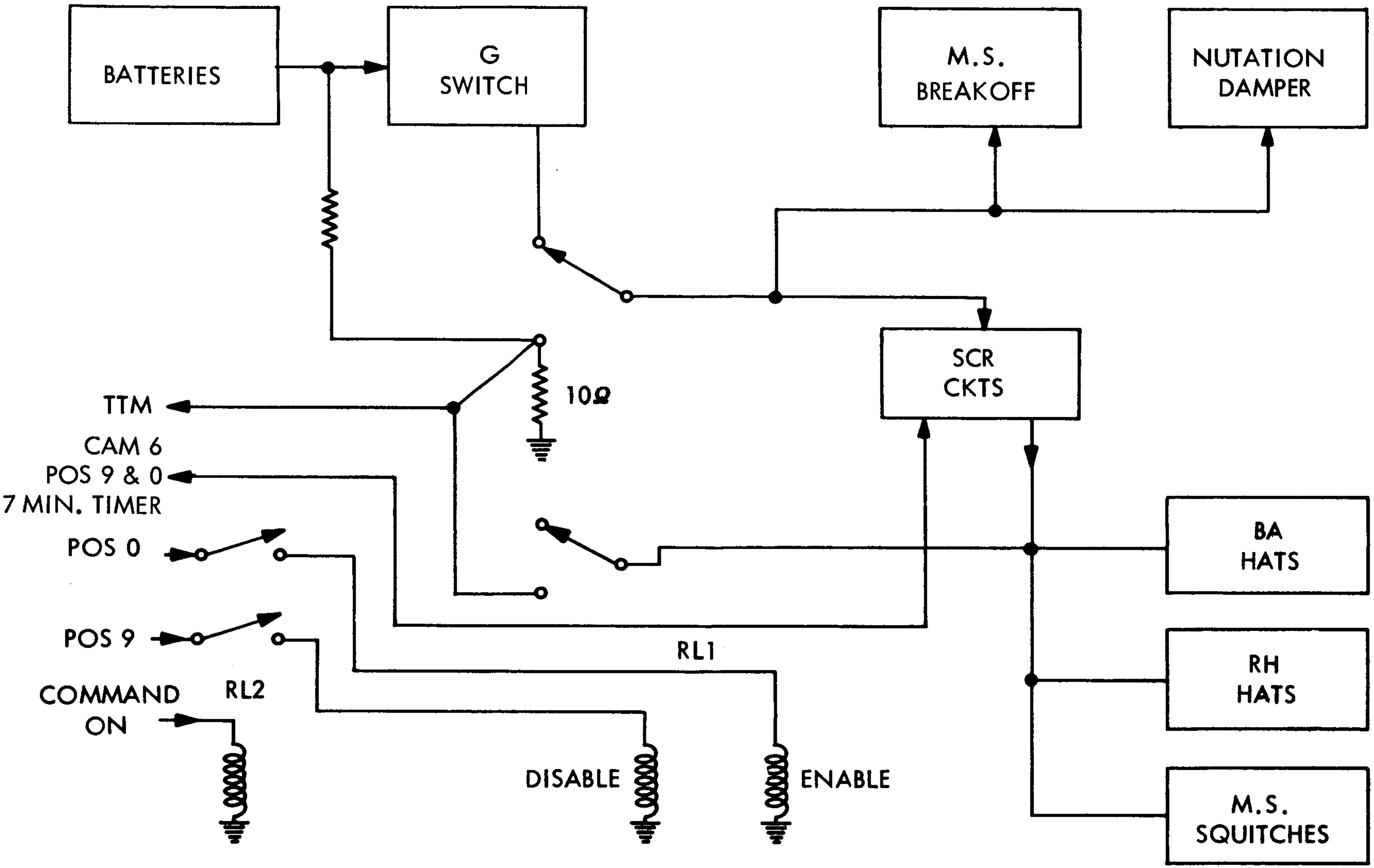


Figure 7–Squib Enable-Disable, Block Diagram

placing the 20 volts from position 9 on the disable coil of the latching relay RLI. The contacts move to place the SCR damper breakoff line at ground potential as well as the output of the SCR circuits. This switching achieves the twofold function of providing ground for pyrotechnic safety during launch countdown and, as mentioned above, of opening the voltage line external to the payload.

IV. CIRCUIT DESCRIPTION

A. Programmer (C1000)

The Explorer XVII programmer is an electromechanical device consisting of a dc motor driving cams mounted on a shaft. When the cams arrive at a desired position, microswitches are opened or closed sequentially in a prescribed format. The programmer (Figure 8) consists of a 28-volt dc motor which gear-drives a shaft on which are located 10 cams. Figure 9 shows the program sequence or format. Command A actuates the programmer electronics, delivering -28 volts to the motor programmer for 15 seconds. Cams 1 and 2, connected in parallel, switch -28 volts to the motor approximately 5 seconds after command or turn-on. These cams are used for a motor interlock function. At the end of one rotation, cams 1 and 2 will open the microswitch delivering the -28 volts to the motor, stopping the motor at the completion of this one rotation. Actuation of cams 4 and 5, occurring 30 seconds after motor start, causes two parallel-connected switches to close their contacts, delivering voltage to the relays associated with the experiments selected. The operation of these relays (latching) turns on the experiments by supplying operating voltages to the experiments. Cams 4 and 5 are connected in parallel for redundancy.

The next event to occur is the actuation of the cam 6 microswitch. This microswitch remains closed for 70 seconds, closing at T = 120 seconds and opening at T = 190 seconds. Closing this switch energizes relays associated with the operation of the ion trap. During the ion trap turn-on time, cams 7, 3 and 8 are used to supply a turn-on for high, medium, and low calibration points for the RH and BA gauges respectively. Cams 9 and 10 cause two redundant switches to close, which in turn energizes the OFF coils of all the experiment relays, optical aspect relays, and telemetry relays that had been turned on by cams 4 and 5. The programmer continues running after this shutdown point until cams 1 and 2 open their respective microswitches. These microswitches open the -28 volts to the motor and the program format is complete.

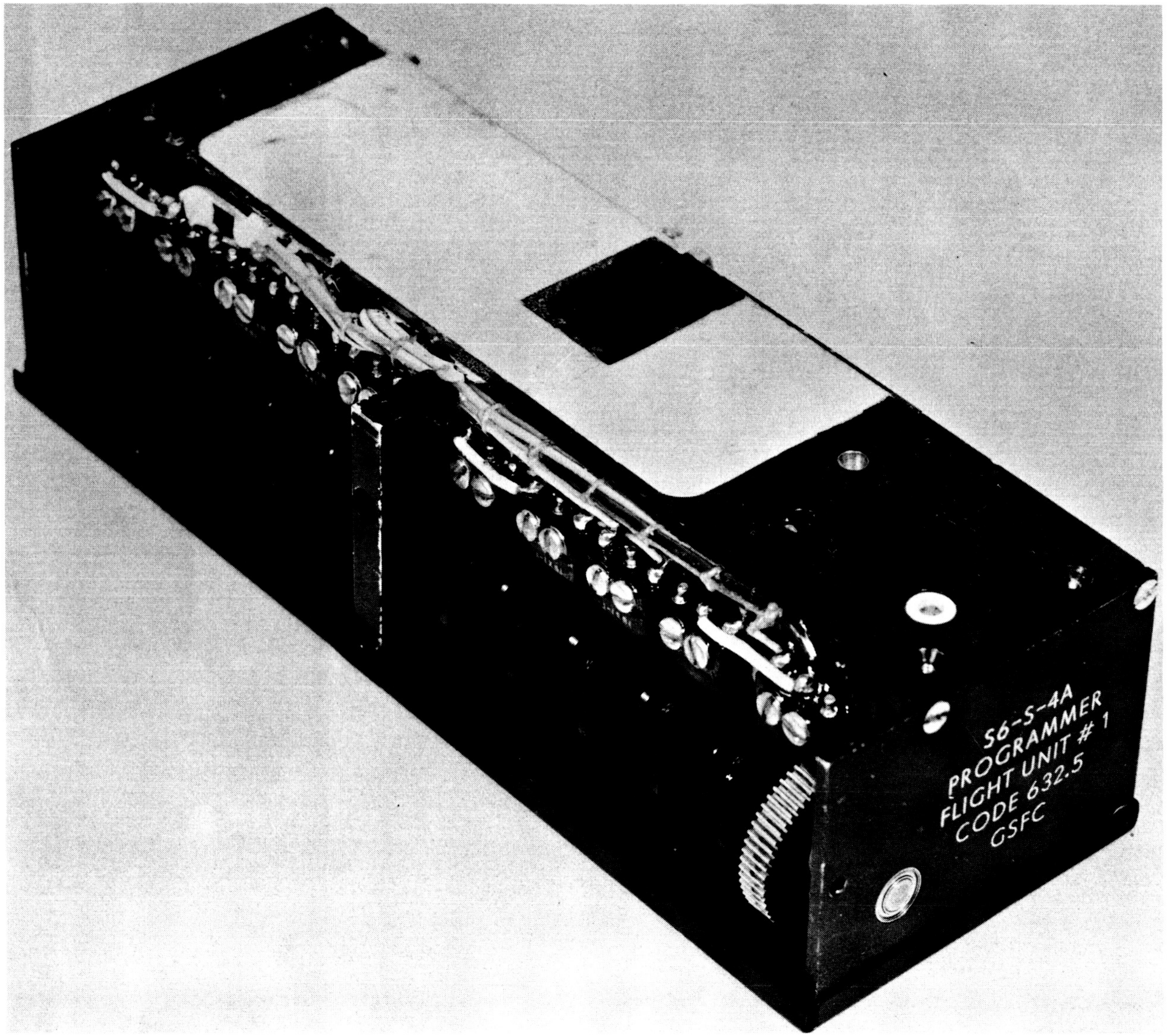


Figure 8-S-6 Motor Programmer

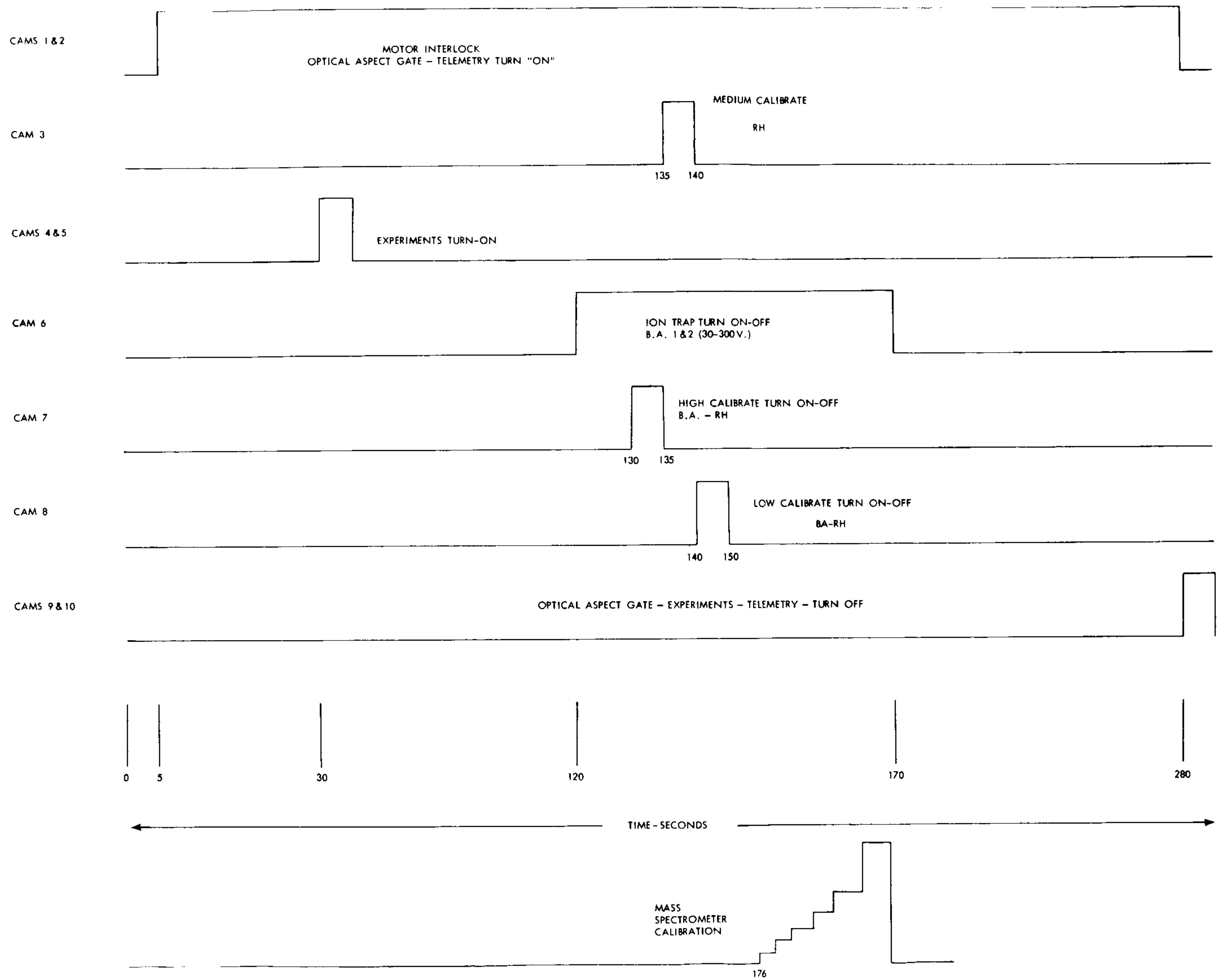


Figure 9-Program Sequence

Switching time for the microswitches is determined by the tooth width on the associated cam. The width of the tooth on all cams (with the exception of cam 6) is approximately 10 seconds; tooth width for cam 6 is 70 seconds.

B. Programmer Electronics (C1200)

The programmer electronics card (Figures 10 and 11) consists of the following electronic functions:

- Motor clock
- ESS clockwise rotation
- ESS counter-clockwise rotation
- 7-minute timer

The motor-start electronics is necessary, as explained previously, to switch -28 volts to the motor for 15 seconds to allow for the actuation of cams 1 and 2 which occurs approximately 5 seconds after T = 0 (command). Figure 12 is a block diagram showing the generation of this 15-second gate. The A1 and/or B1 output of the two command receivers is differentiated by the input condensers C20 and/or C22 (Figure 13). The resulting pulse is coupled through the emitter-follower (Q9). This output pulse triggers the pulse generator Q10. This pulse generator circuit utilizes a silicon controlled rectifier (SCR) which, when turned on, will dump the voltage stored on C10 into the load R27. Because of the large value of R26 (47K ohms), insufficient holding current is developed to maintain the SCR conduction and it therefore resets. The output pulse (13.5 volts amplitude and 3 milliseconds wide) triggers the SCR Q12, which in this case is used as a battery gate. This pulse also turns ON Q15, which is part of the 7-minute timer and will be discussed later. The conduction of Q12 delivers 13.5 volts to the unijunction, Q13; it also drives Q14 into conduction, energizing the relay RL1. The contact closure delivers -28 volts to the motor programmer for the 15-second period of the oscillator. This time constant is determined by the RC time of R30, R31, R32, R34 and C11. The voltage on the emitter of Q13 rises to 13.5 volts at this RC rate until the E-B1 breakdown voltage of Q13 is reached. When Q13 conducts, a pulse is derived at R34 which drives Q11 into conduction. The grounding of the gate of Q12 by the conduction of Q11 drives Q12 out of conduction, thereby resetting the timing circuit as well as opening the relay contacts delivering power to the motor. R34 is an NTC resistor used to compensate the accuracy of the timing circuit; this accuracy is approximately 3 percent over a temperature range of -10 C°to +60°C.

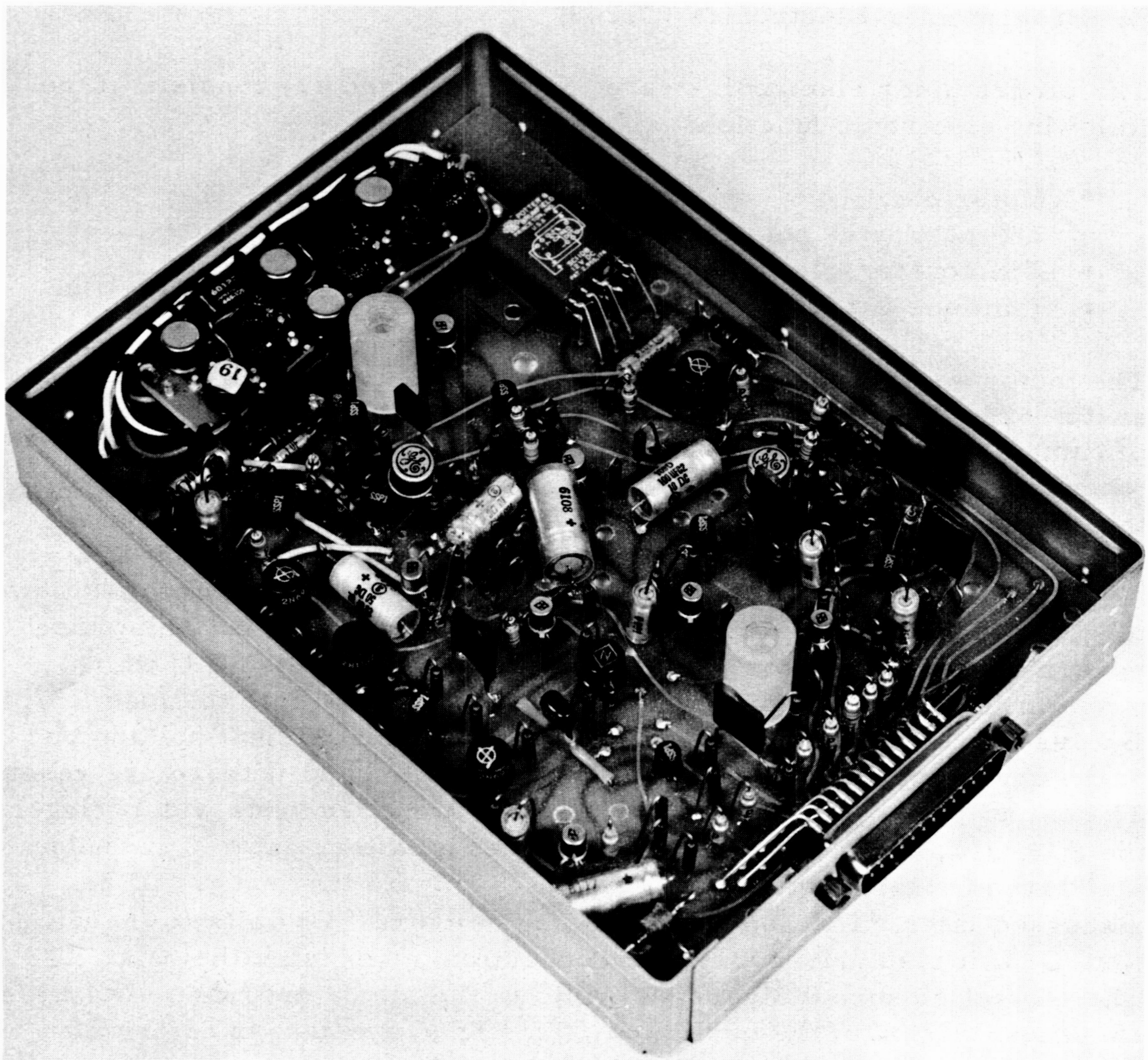


Figure 10–Programmer Electronics, Top View

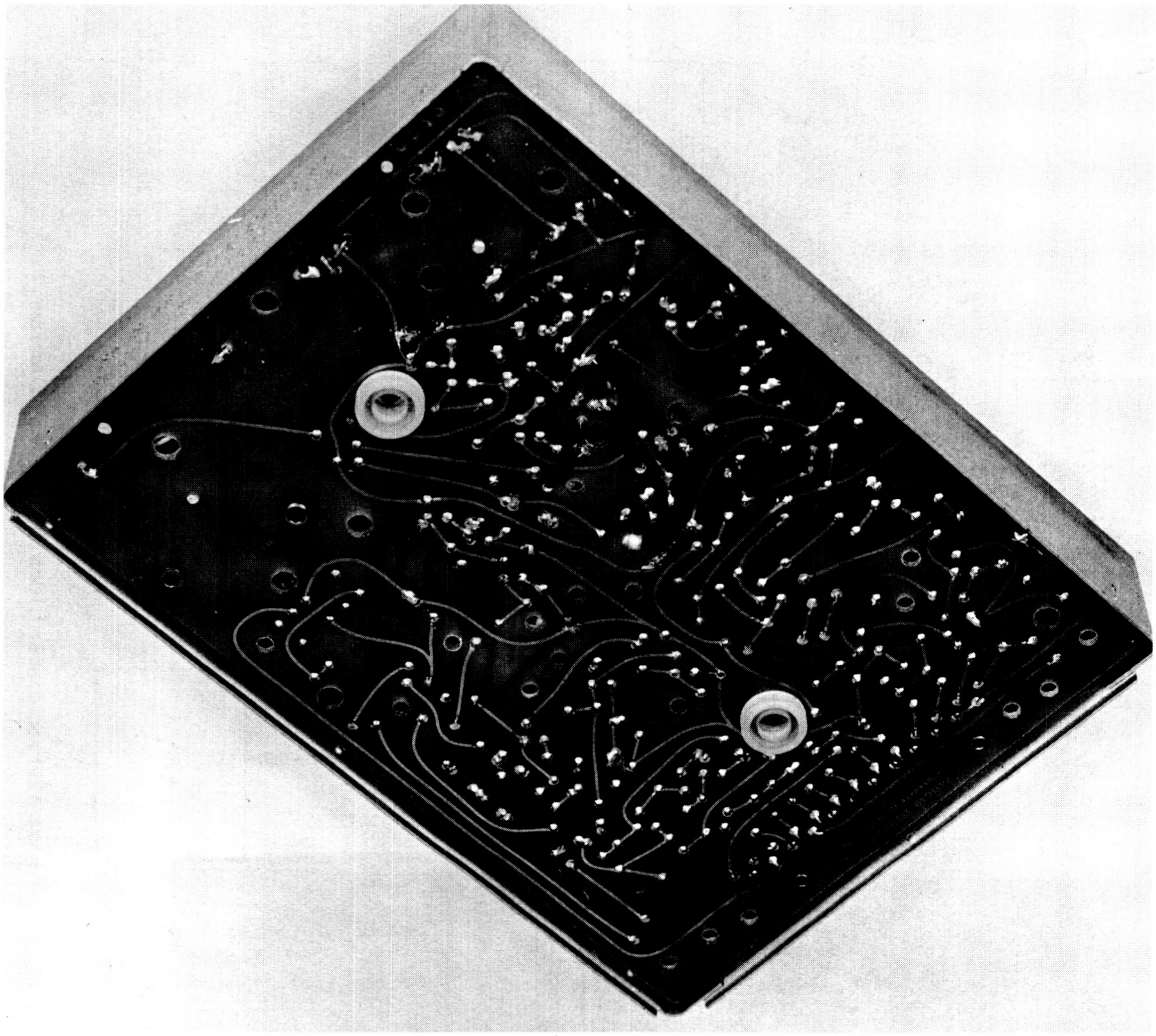


Figure 11-Programmer Electronics, Bottom View

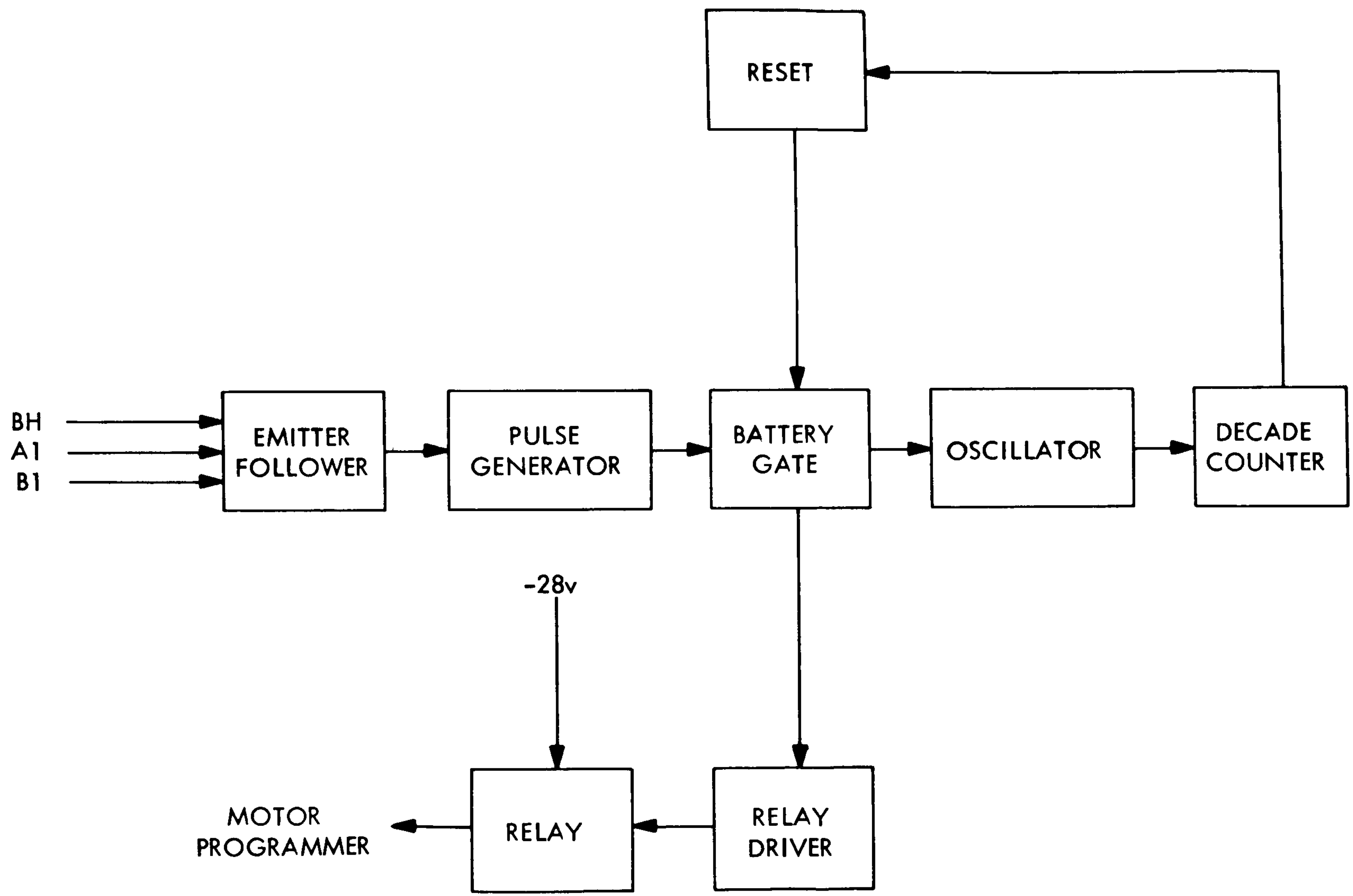


Figure 12-Programmer Electronics, Block Diagram

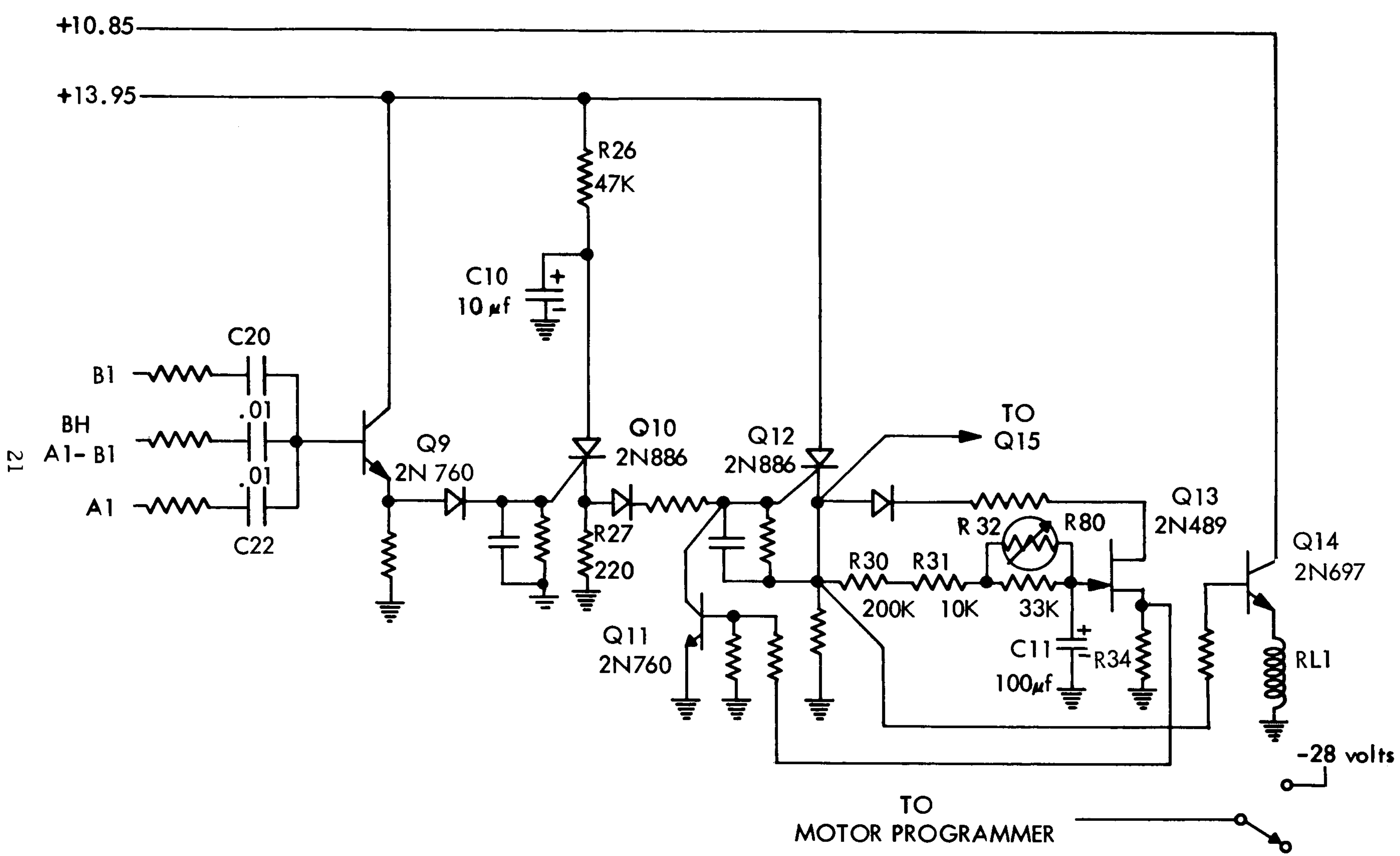


Figure 13-Motor Programmer Electronics

The experiment selector switch command-clockwise and command-counterclockwise electronics are identical in circuitry. Their outputs drive separate relays for the corresponding rotation. Therefore, it will only be necessary to describe the electronics (Figure 14) associated with one circuit.

In the case of command-clockwise rotation (Figure 15) command B1 from the command receiver enters D2, is integrated by C2, and drives Q1 (an emitter-follower) to conduction. This output drives the SCR (Q2) into saturation. Because of the large anode resistor (R5), insufficient holding current does not allow Q2 to remain in conduction and it therefore is reset. The negative going output pulse drives Q3 (inverter-amplifier) into saturation. The positive output pulse controls the emitter-follower Q4, whose output drives the experiment-selector switch in the clockwise direction.

The 7-minute timer (Figure 16) is started by any one of three commands. As explained previously, the timer starts with programmer command to back up the programmer in case of its failure during a run. The timer also starts when commanding the experiment selector switch to position 9 (all "ON"). The command ON signal is delivered to the gate of the power switch Q15 (Figure 17). Q15, driven ON, delivers operating voltage to the unijunction oscillator (Q16) as well as driving Q17 to conduction. With B+ delivered to base 2, the emitter of Q16 starts rising at the RC rate of R41, R42, R43, R44 and C12. At this RC rate it takes approximately 4.3 seconds to reach the unijunction breakdown. With breakdown at the E-B1 junction, the condenser C12 is discharged into R45, delivering a pulse of approximately 4 volts at B1. The charge cycle commences again to the breakdown point, thus defining a relaxation oscillator. The pulse output of Q16 drives Q19, an SCR in the "starved" mode, which is turned on for the RC duration of R48-C14. This output is the driver source for the decade counter.

The decade counter is a multipulse magnetic counter having as its circuit element a single toroidal core of square hysteresis loop material driven in a number of discrete steps from one saturated state to the opposite state. For 10^2-to-1 countdown, three cores are used: one for forming the input pulse, and one for each of the two decade counter stages. The magnetic core may be thought of as a bucket which will hold a fixed quantity of flux; the bucket is filled by an integral number of ladles of flux of constant magnitude. To ensure constant-volume ladles, the counter stage is driven by another counter stage or from a pulse-forming circuit that provides this constancy. In either

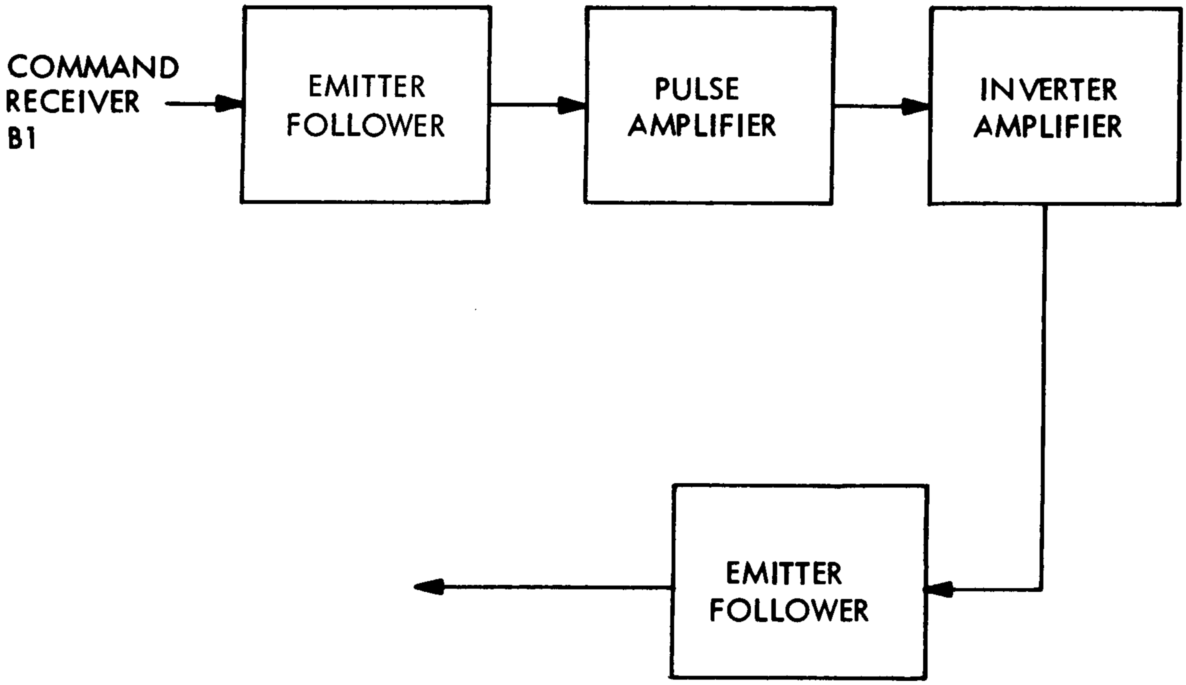


Figure 14-Experiment Selector Switch Electronics, Block Diagram

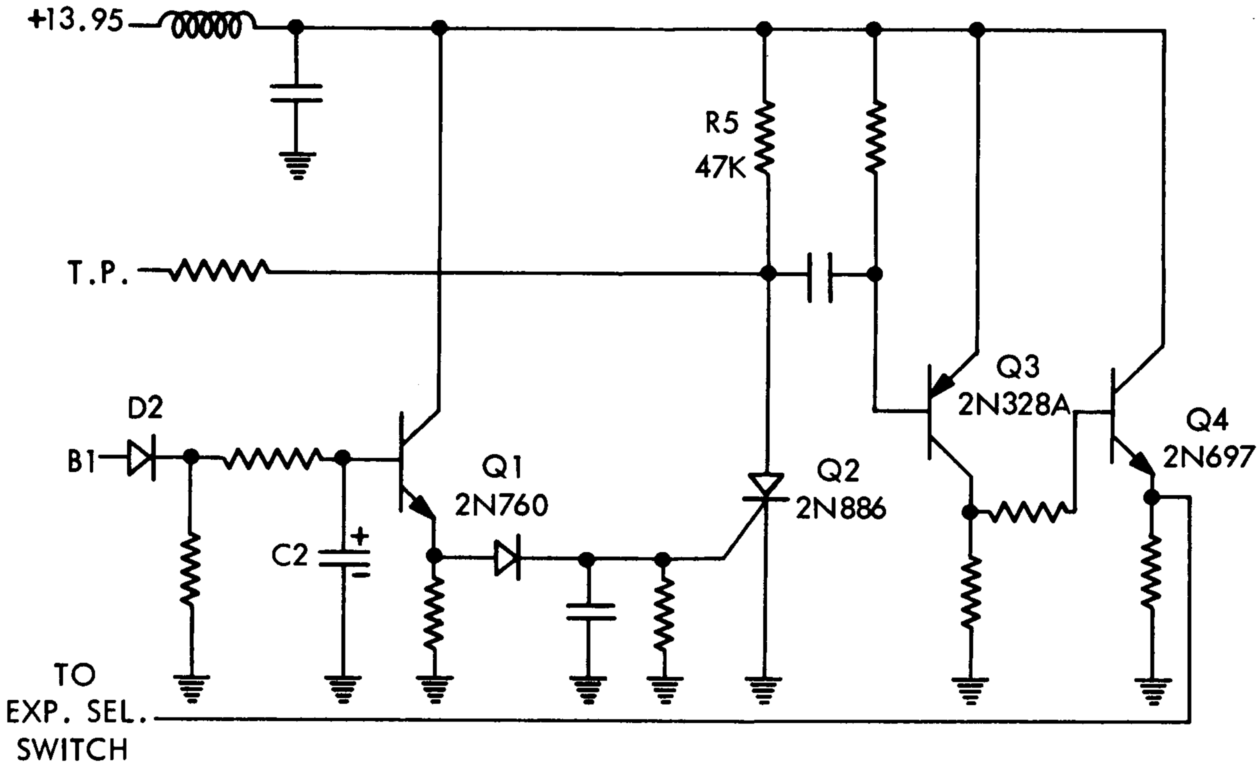


Figure 15-Experiment Selector Switch, Clockwise Command Electronics

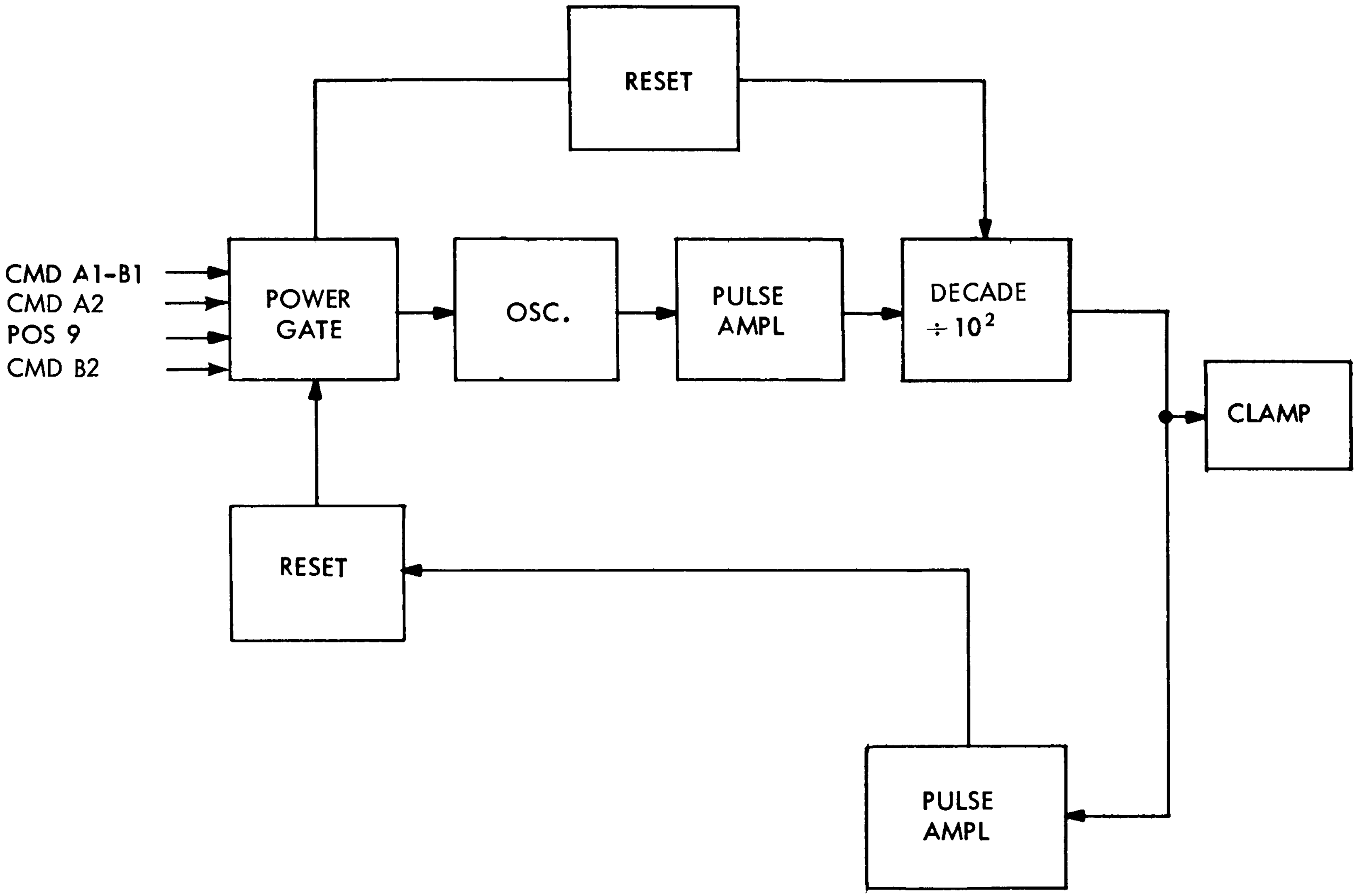


Figure 16–7-Minute Timer, Block Diagram

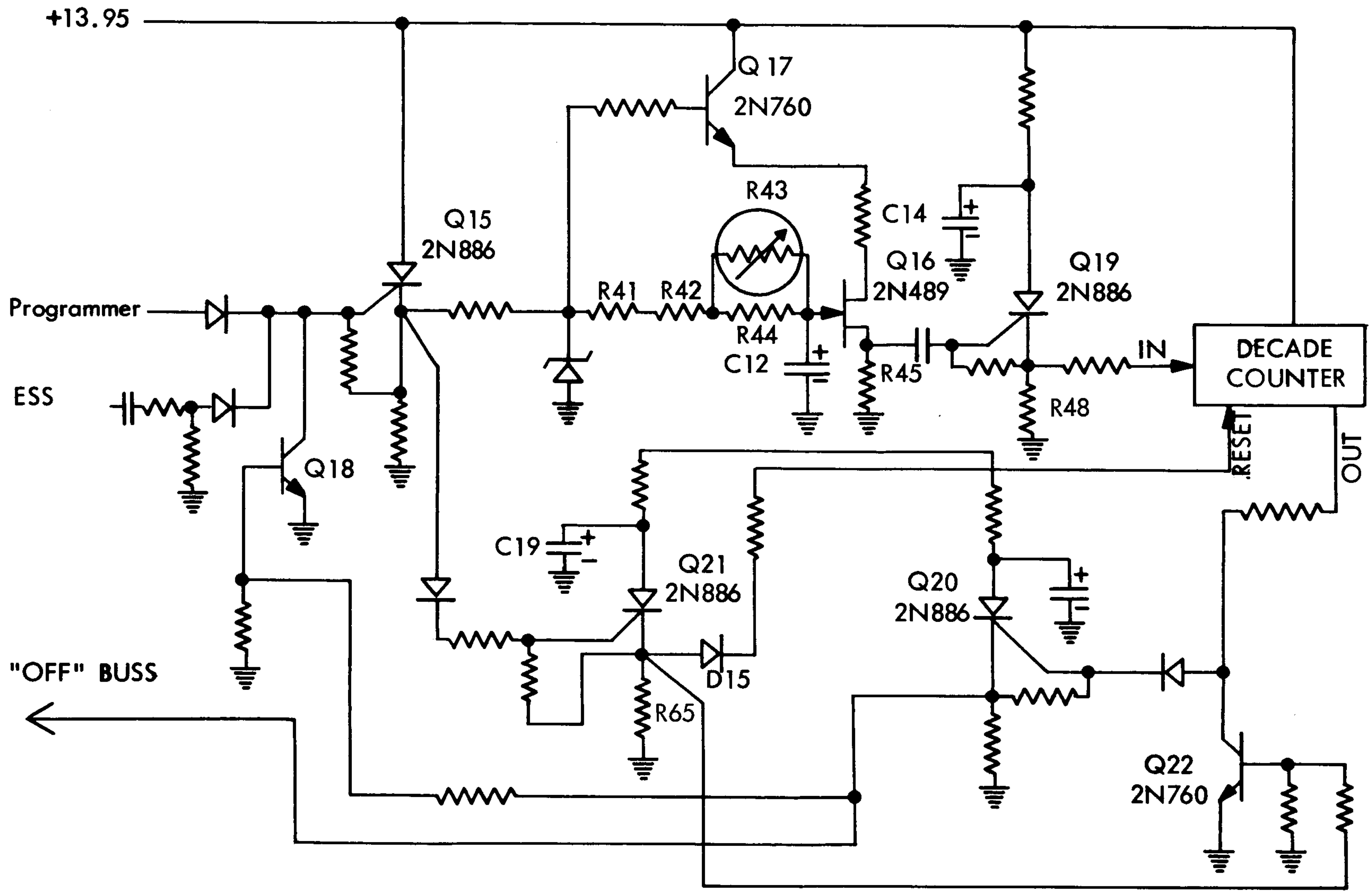


Figure 17-7-Minute Timer, Schematic Diagram case, successive pulses of constant volt-second area (representing ladles) are applied to the core winding. When the required number of these pulses has been applied, the core will be driven to positive saturation. The fall of the last input pulse is arranged to trigger a second transistor in the circuit, which then drives the core out of positive saturation and back to negative saturation. When negative saturation is reached, the circuit is at its initial state. Taking the core from one negative saturated state to positive saturation provides a pulse of fixed volt-second area in the output winding. The output pulse from each counting stage may thus be used as a ladle of constant volt-second area to fill the next counter. Figure 18 shows the fabrication of an Incremag decade counter.

The output of the counter occurs 7 minutes after turn-on or start. This output pulses the starved SCR (Q20) to the ON position, dumping the voltage stored on C15 into the emitter load (R55).

This output achieves two functions:

(1) Stops the unijunction oscillator by turning off the power gate (Q15) supplying power to the oscillator. This turn-off is achieved by the action of Q18 which, when saturated by the amplified decade output, resets the SCR (Q15).
(2) Turns off all the experiments that had been turned ON either by a programmer function or an experiment-selector switch function.

A necessary operation in the use of the decade counter is to provide a means of resetting the magnetic cores either before or after a timing cycle to ensure against any flux storage in the cores. In this application, the cores are reset at the initiation of the timing cycle. The turn-on of the battery gate Q15 turns Q21 on, generating a positive pulse at the emitter of Q21 with a pulse duration of R65-C19. This amplified pulse is coupled through D15 to the reset windings of the two decade windings. These cores are saturated and any stored flux is taken from the cores, thus readying the cores for the timing cycle.

It is inherent with the decade counter to deliver an output pulse when the cores are reset; therefore, this output pulse must be clamped or dampened to prevent Q20 from firing at the reset time. This is achieved by using the reset pulse from Q21 to saturate Q22, starting the output pulse from the decade counter at this time only.

The complete circuitry for programmer electronics card C1200 is shown in Figure 19.

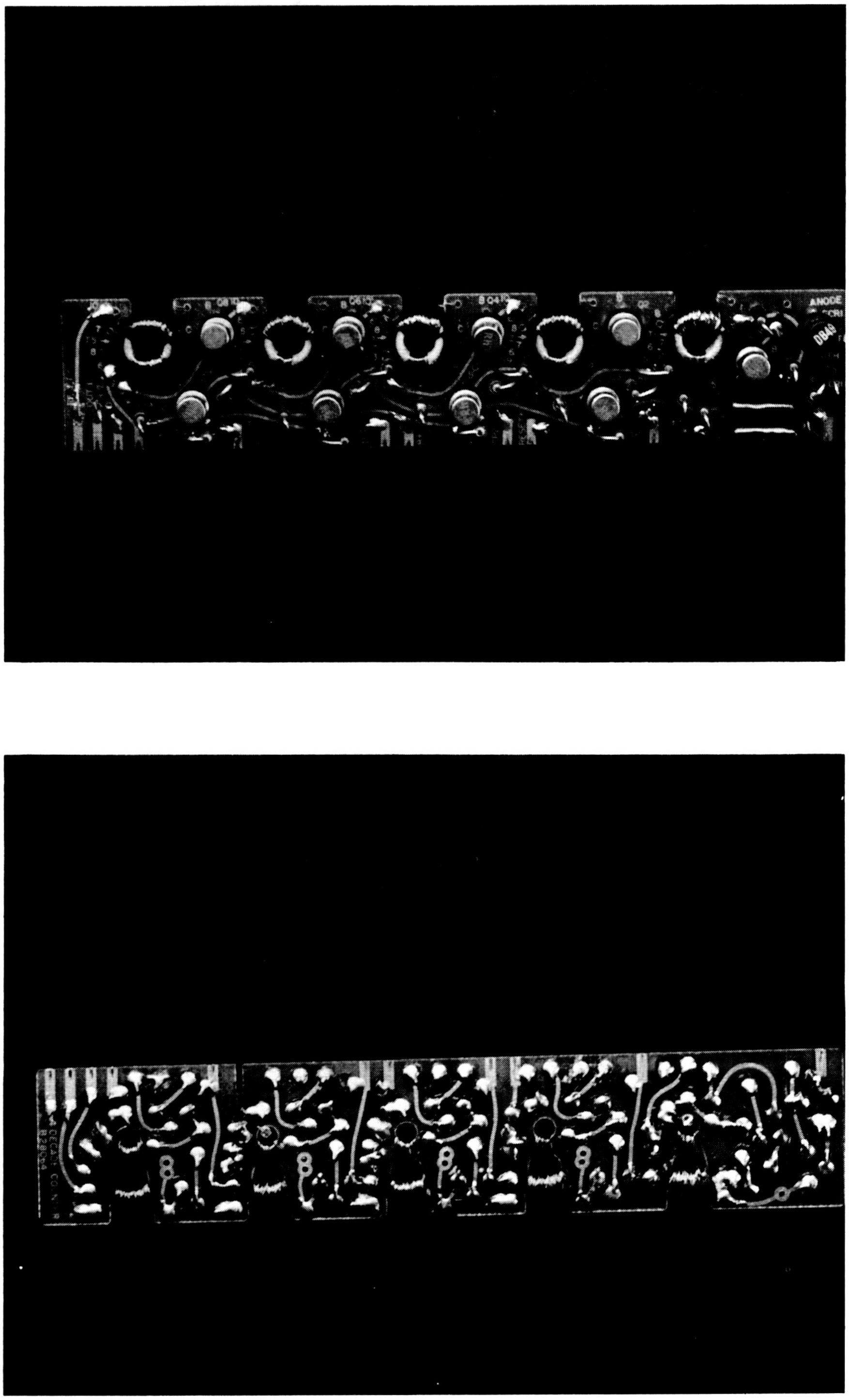
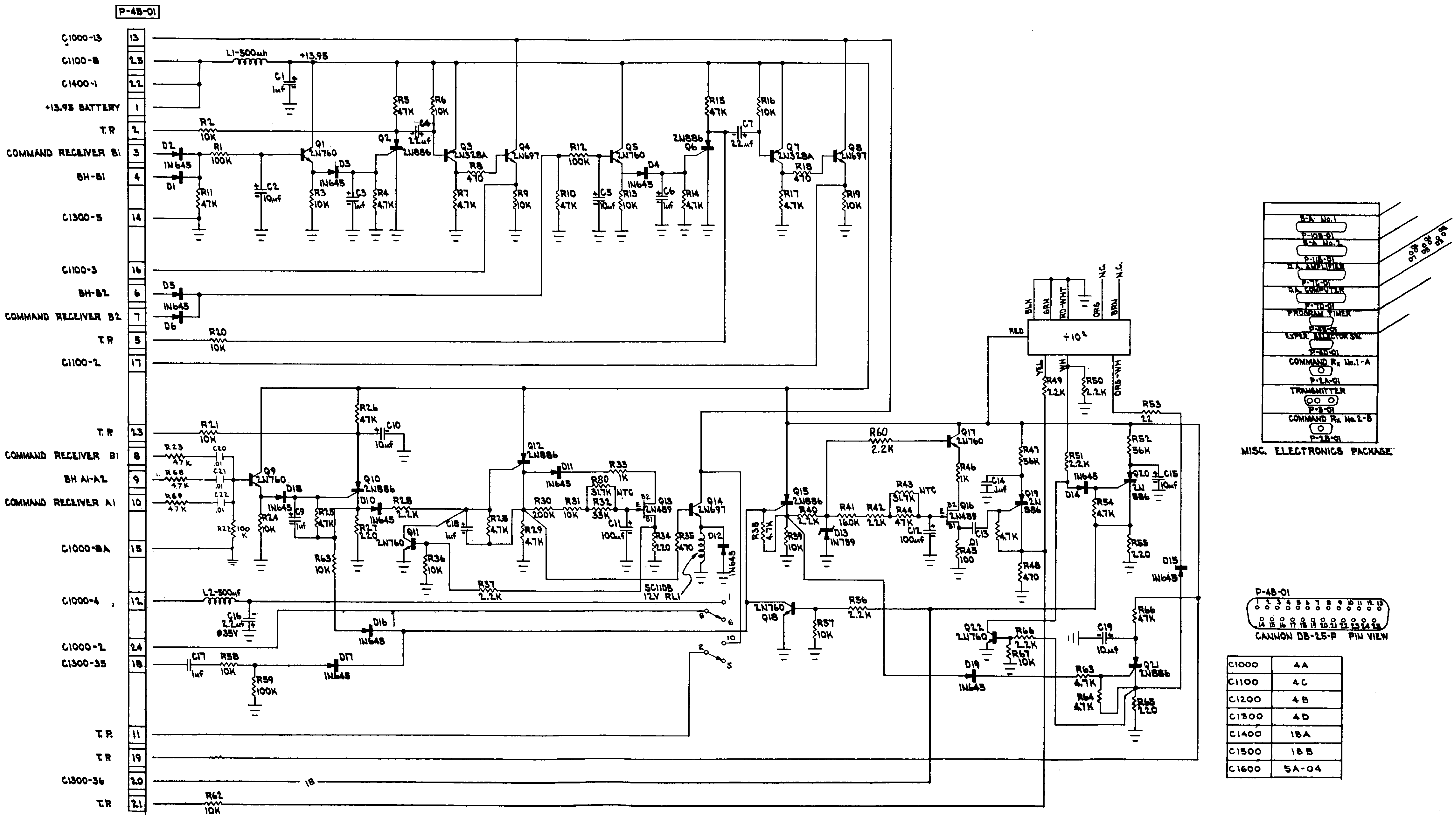


Figure 18–Incremag Decade Counter



C1000	4A
C1100	4C
C1200	4B
C1300	4D
C1400	18A
C1500	18B
C1600	5A-04

Figure 19-Programmer Electronics, Schematic Diagram

C. EXPERIMENT SELECTOR SWITCH (C1100)

The experiment selector switch (Figure 20) is an electromechanical device consisting of a Syncramental* motor drive, a 6-deck, 10-position wafer switch, and an electronic position-data matrix. The motor is energized by one of two relays depending on selection of clockwise or counterclockwise rotation. As seen in Figure 21, the energizing of RL1 places -28 volts through the relay contacts to the counterclockwise coil of the motor, while the energizing of RL2 places -28 volts through the relay contacts to the clockwise coil of the motor.

The motor shaft is mechanically coupled to the switch shaft. The switch decks are assigned as follows:

Deck No.	Function
1	Position data
2	Manual ON - OFF
3	Mass spectrometer (MS)
4	Redhead (RH)
5	Bayard-Alpert (BA)
6	Electron temperature probe (ETP)

The arms or wipers of the four experiment switch decks connect cams 4 and 5 of the programmer (when commanded) to the relay field of the experiment or experiments selected. The switch position format allows for individual experiment selection turn-on, combinations of experiment selection turn-on, and a manual ON - OFF for all experiments independen' of the programmer.

Switch Position	Experiment Selected
1	BA (Bayard-Alpert)
2	MS (mass spectrometer)
3	RH (redhead)
4	ETP (electron temperature probe)
5	RH+BA+ETP+MS
6	MS+BA+ETP
7	MS+RH+ETP
8	ETP+BA+RH
9	All ON (manual)
0	All OFF (manual)

*Trade name of a motor manufactured by G. H. Leland Co. Inc., Dayton, Ohio

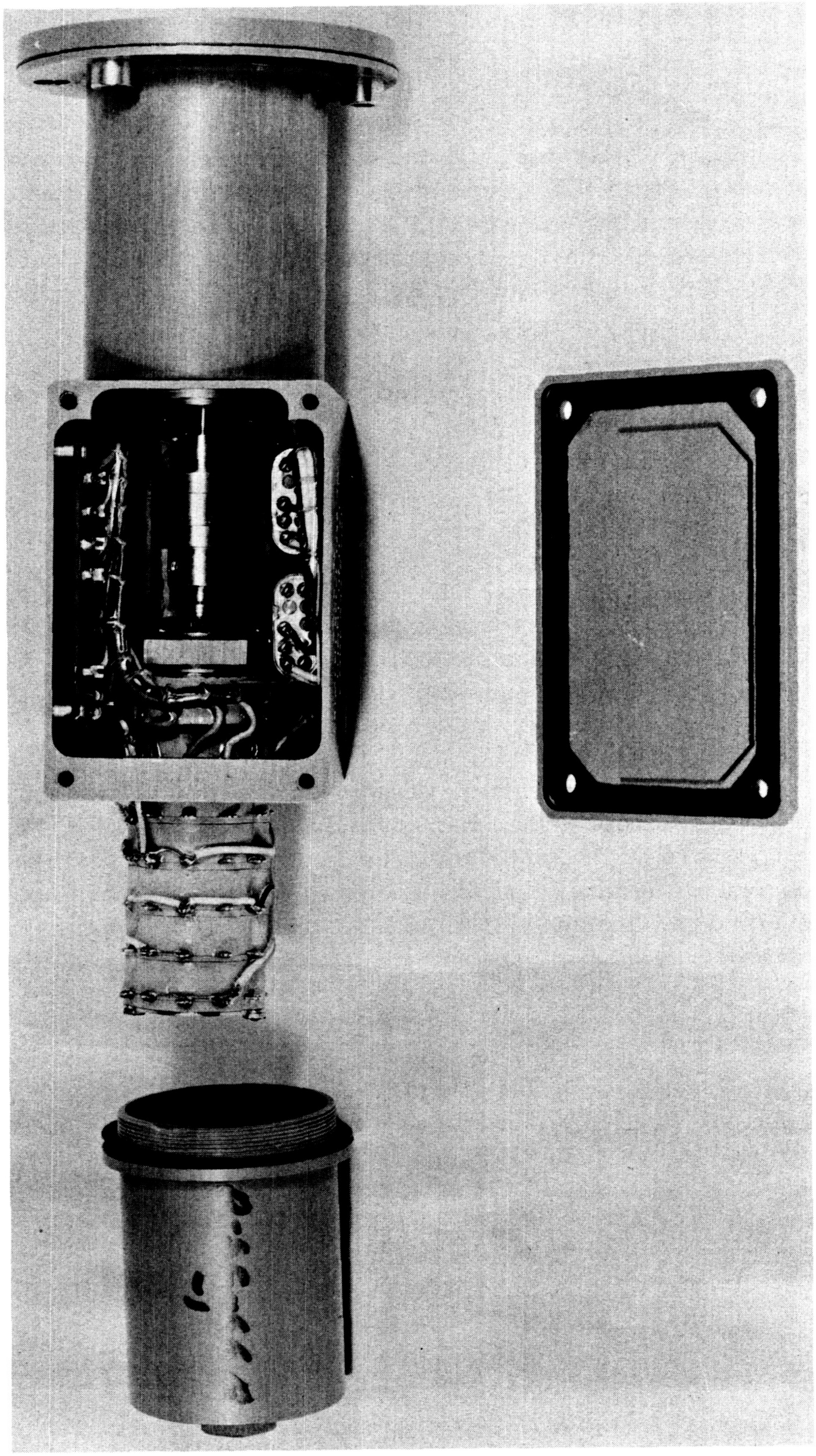


Figure 20–Experiment Selector Switch

NOTES:
1. ALL DIODES ARE IN645; ALL RESISTORS ARE 100 K.

SWITCH POSITION	EXPERIMENT SELECTED
1	BA
2	MS
3	RH
4	ETP
5	RH+BA+ETP+MS
6	MS+BA+ETP
7	MS+RH+ETP
8	ETP+BA+RH
9	ALL ON (MANUAL)
0	ALL OFF (MANUAL)

C1000	4A
C1100	4C
C1200	4B
C1300	4D
C1400	18A
C1500	18B
C1600	5A-04

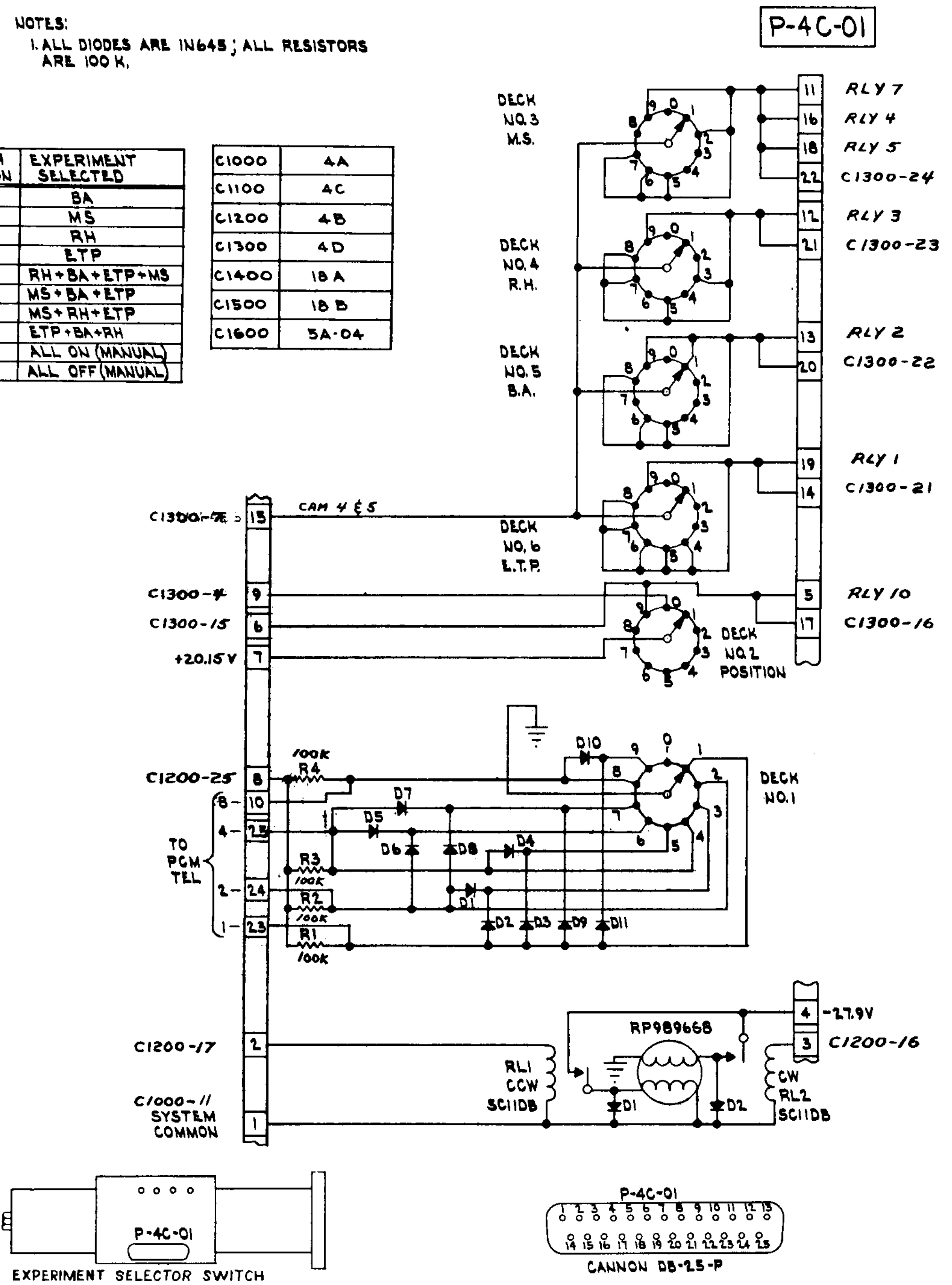


Figure 21-Experiment Selector Switch, Schematic Diagram

As all the switch decks are ganged together it can be seen that, for switch position 1, cams 4 and 5 are connected (through deck 5) to the Bayard-Alpert experiment relays.

These experiment relays are of the latch type. The 10-second pulses delivered by cams 4 and 5 energize the ON coils of the latch relays, while either cams 9 and 10 or the 7-minute timer will energize the OFF coil of the relay associated with the experiment. These relays are located in the relay module (Figure 7A in the appendix).

If the selector switch is moved to position 5 by command, it can be seen that when cams 4 and 5 actuate, the derived pulse actuates the MS experiment relays through deck 3, the RH experiment relays through deck 4, the BA relays through deck 5 and the ETP relays through deck 6.

Deck 1 is used to provide a binary code from a diode matrix to the PCM transmitter to identify the shaft position of the switch. Applying the ground rules of +E = 0 and 0 (volts) = 1, it is seen that, in position 0 of the switch, a voltage will appear on the 1, 2, 4, 8 lines of the diode matrix. When the switch is moved to position 1, the switch arm grounds the output side of R1, thus delivering a 1 to the PCM telemetry. It follows that if the switch is in position 7, a binary 7 is generated by grounding D7, D6, and D3, giving zero volts at line 4, 2, and 1.

Deck 2 is used in position 9 to energize the electronics (S6-S-4D) driving the ON coil of all the relays associated with the four main experiments. Position 0 therefore energizes the electronics driving the OFF coils of all the relays associated with the four main experiments.

D. Experiment Selector Switch Electronics (C1300)

The experiment selector switch electronics (card C1300) (Figures 22 & 23) provides an ON and OFF bus line to the ON and OFF coils respectively of the telemetry, optical aspect, and experiment relays. The steering logic is also incorporated in this card.

The output of Q1 (Figure 24) drives a relay (RLI) ON for the RC duration of C1 x the relay coil resistance. Energizing the relay closes its contacts, delivering 10.85 volts to the OFF bus line. The SCR turn-on is accomplished with an input signal either from position 0 of the experiment selector switch or from the output of the 7-minute timer. The output line is directed to the OFF coils of the four main experiment relays. The output from cams 9 and 10 is also diode (D3) coupled to this OFF bus line.

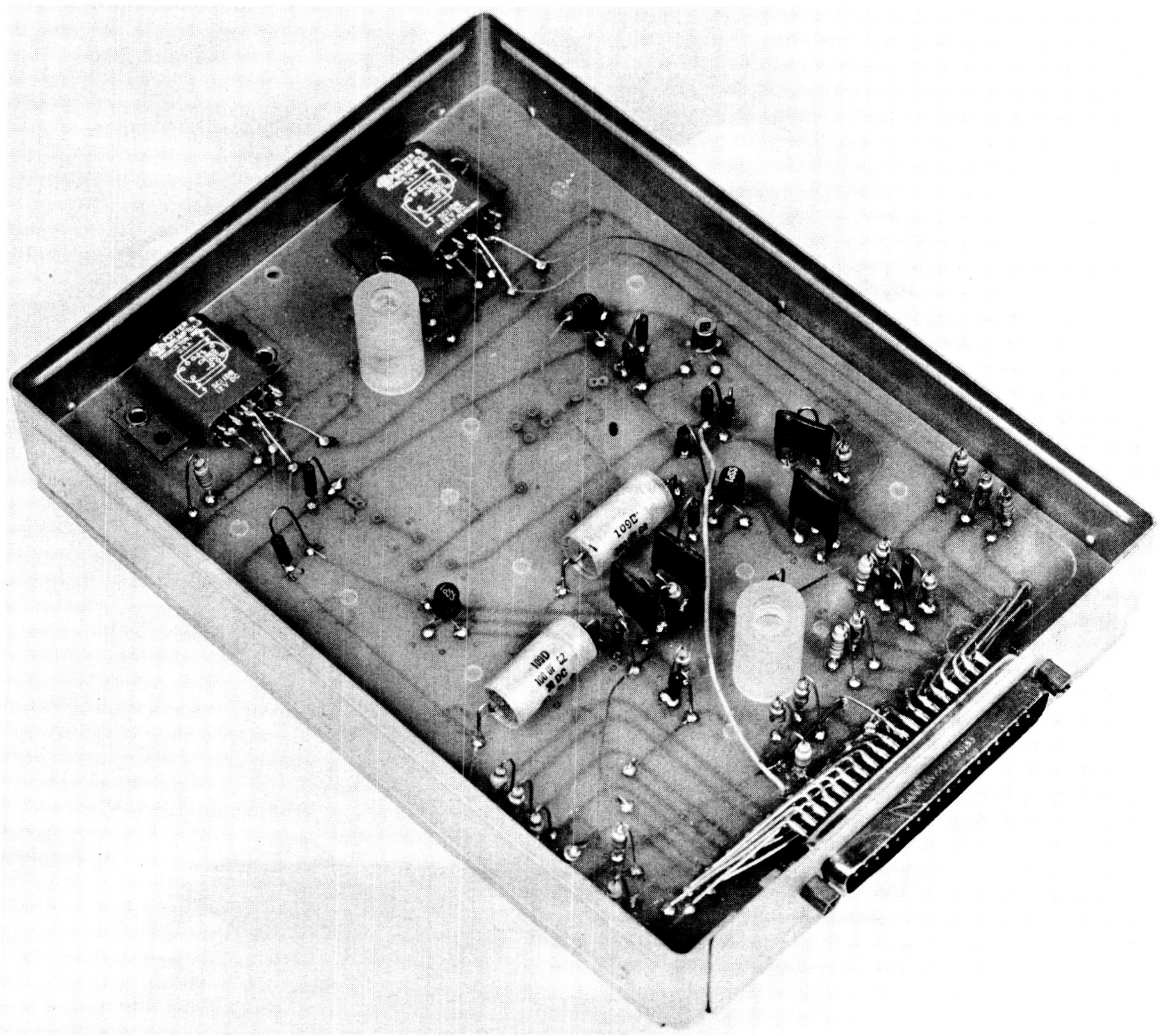


Figure 22-Experiment Selector Switch Electronics, Top View

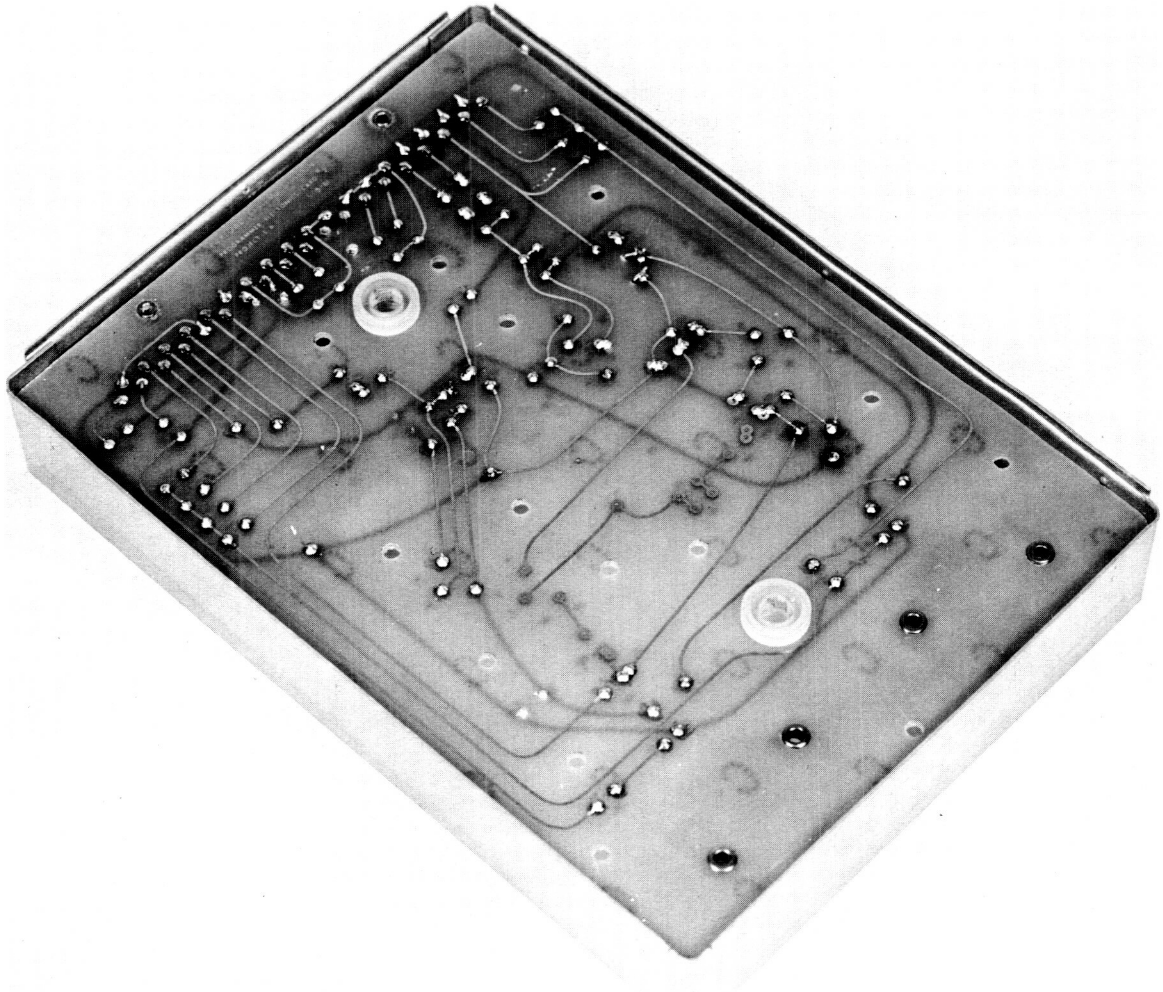


Figure 23-Experiment Selector Switch Electronics, Bottom View

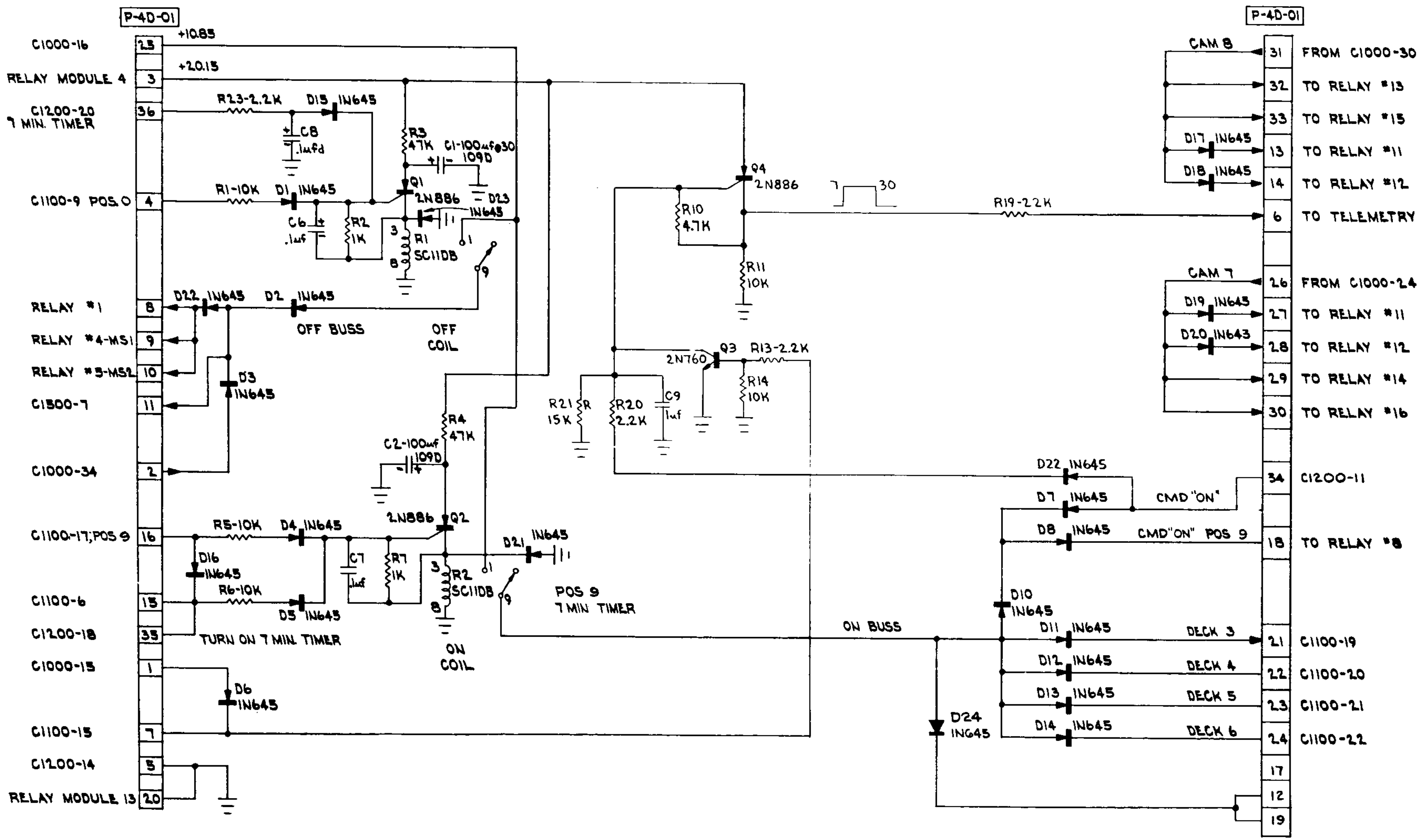


Figure 24-Experiment Selector Switch Electronics, Schematic Diagram

The ON bus line is developed from the contacts of RL2. When Q2 is turned ON, the voltage stored on the condenser C2 is dumped in to this relay. The SCR automatically resets, as insufficient holding current is allowed to pass through it (due to large R4). The SCR is turned ON by an input signal through position 9 of the experiment selector switch; position 9 is also coupled to the 7-minute timer by D16. The output of the relay contacts is diode-coupled to the appropriate decks of the experiment selector switch and, depending on its position, turns ON those selected experiments. The output is also coupled by D8 and D10 to the telemetry relay.

E. Squib SCR Circuitry (C1500)

The squib-control circuit card (Figure 25 and 26) consists of two SCR circuits which have redundant operation for pyrotechnic actuation. Cam 6 triggers the SCR Q1, applying the supply voltage (9.3v) to the squib resistance box. A 5-ohm, 1/2-watt resistor is in series with the squibs or caterpillar motors. Testing has shown that 80 percent of actuated squibs remain shorted instead of opening; the resistors protect the power supply in this event by burning out, thus opening the line.

The output of Q2 is paralleled with Q1 for redundancy. The firing signal, however, is either cams 9 and 10, the output of the 7-minute timer, or position 9 of the experiment selector switch.

Figure 27 is a schematic drawing of the squib SCR circuitry.

F. Mass Spectrometer Calibrators (5A04)

A sequential voltage calibration (Figure 28) is provided for each mass spectrometer experiment. These calibrators are fabricated on two cards, one identified as the calibrator electronics and the other as the sequencer electronics.

The calibrator electronics consists of a voltage converter, a resistance-divider network, an AND gate, a 20-second timer, and a switching relay. The sequencer electronics is a ring counter driven by a 2-second oscillator. The 2-second outputs drive relays which switch their respective outputs across a 20K ohm load in the feedback loop of the electrometer amplifier. This amplifier is logarithmic in that it compresses the input signal of 0 to 20 volts into a 0-to-5-volt output to the telemetry transmitter.

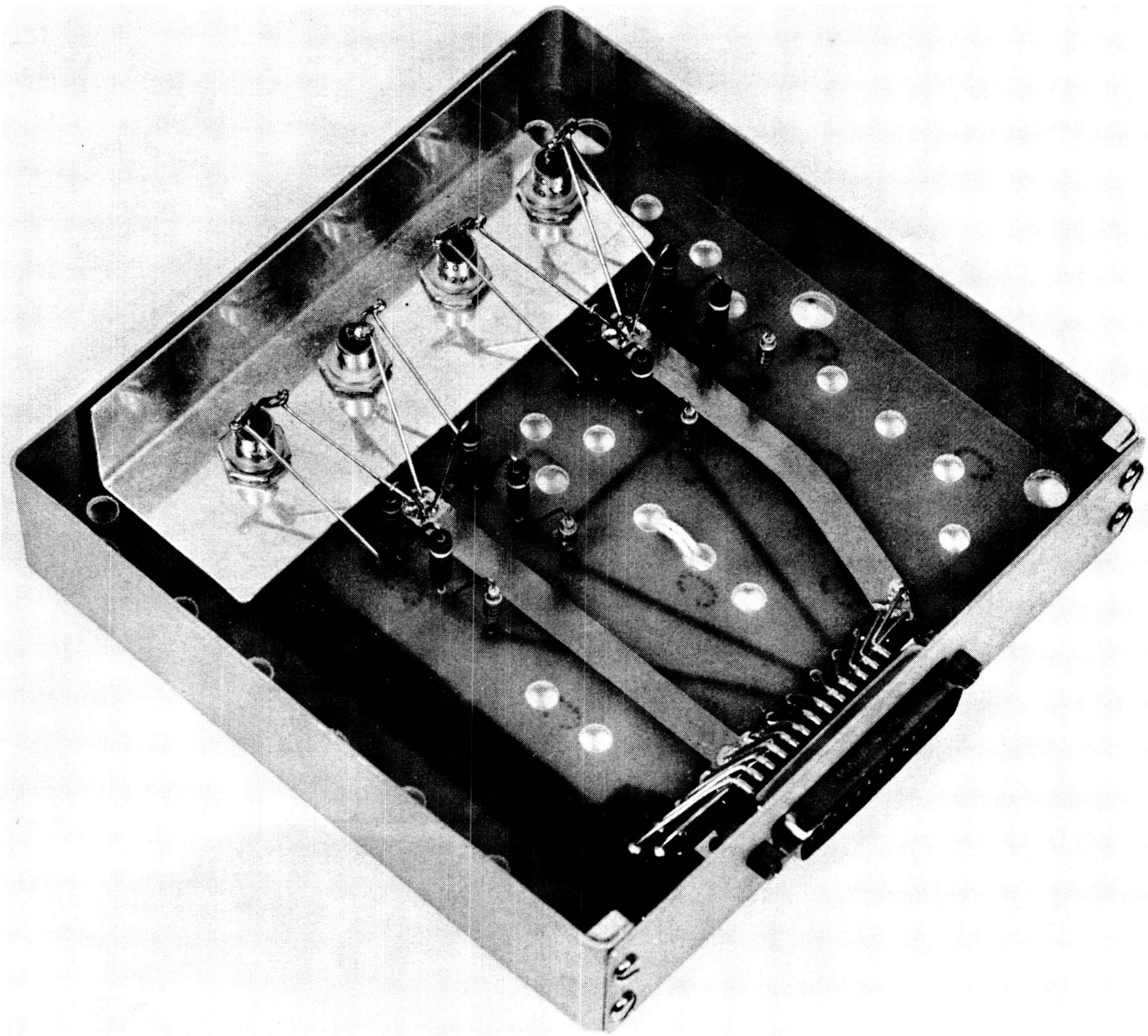


Figure 25-Squib Control Card, Top View

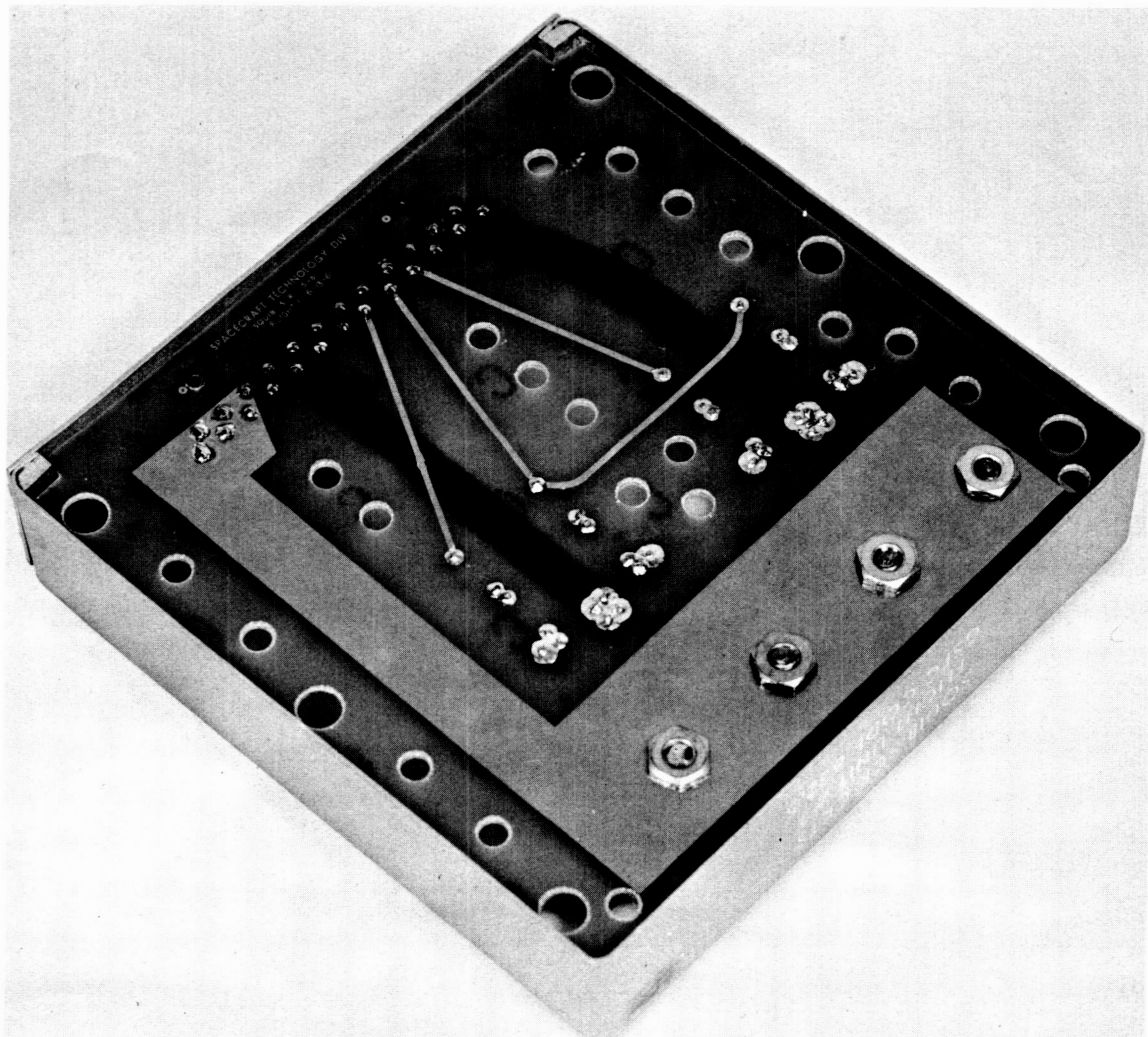


Figure 26–Squib Control Card, Bottom View

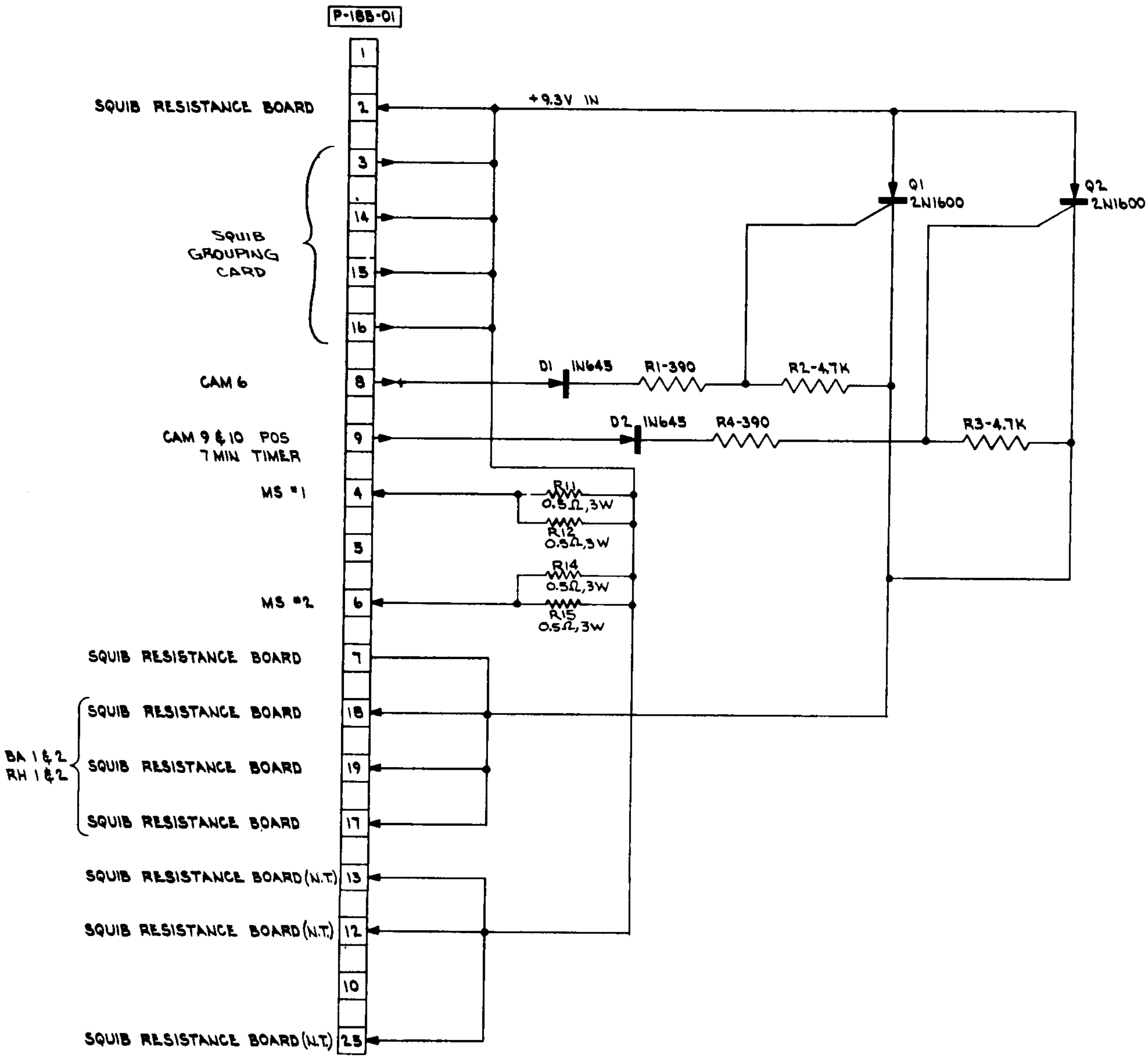


Figure 27-Squib Silicon Controlled Rectifier, Schematic Diagram

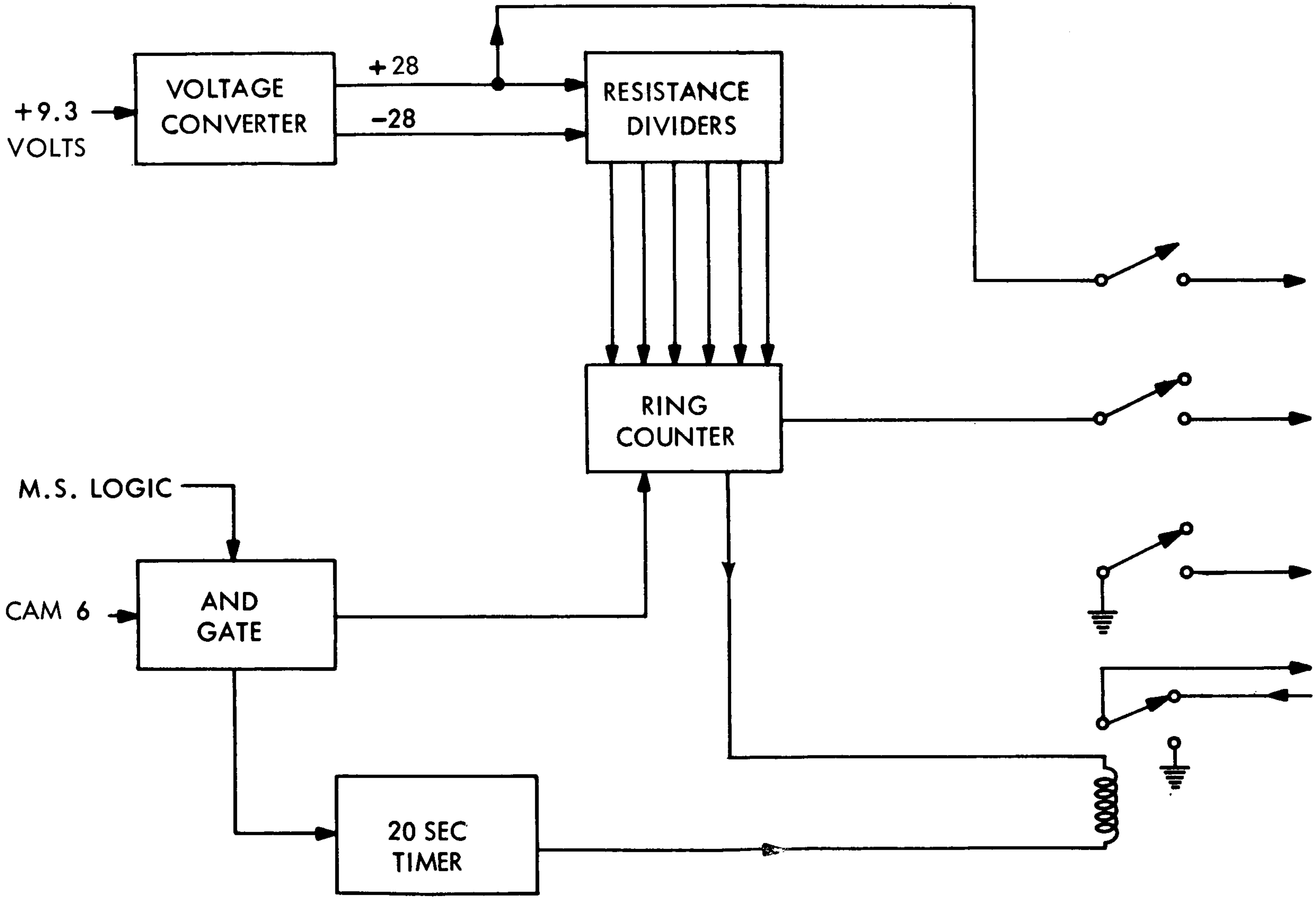


Figure 28-Mass Spectrometer Calibrator, Block Diagram

Because the calibrated voltages are switched into the feedback loop of this amplifier, it is necessary to maintain a high impedance level with respect to ground. To derive the calibrated voltages of ground, 0.01, 0.03, 0.1, 0.3, 1.0 and 10 volts, a voltage converter* is used to convert the 9.3-volt line from the battery to a floating +28- and -28-volt system.

Across the output of the converter power supply is a high-impedance resistance-divider network, which divides down this output into the six voltage levels into 20K ohms. The six levels are applied individually to normally open contacts of six relays. The relays are stepped in sequence every 2 seconds so that the seven outputs are switched in sequence to the contacts of relay RL1.

The relay is a double-pole double-throw switch which

- Switches the sequenced voltages to the electrometer feedback resistor
- Switches common side of the voltage converter to the feedback resistor
- Provides a ground to the mass spectrometer logic which stops the logic clock
- Provides a ground to the telemetry encoder which flags the operation of the calibration time for ground station data reduction

The calibrator is commanded to start by coincidence through the AND gate of cam 6 (T_{PRO} = 120 seconds) and the end of the second sequence of the mass spectrometer logic (leading edge of LO re-zero of MS sample time). This coincidence starts the ring counter and a 20-second timer in the calibrator electronics card. The 20-second timer supplies RL1 with B+, while the turn-on of the ring counter applies ground to the other side of the RL1 coil. The purpose of the 20-second timer is for fail-safe operation. The redundancy allows the closure of RL1 for 20 seconds to achieve its 14-second calibration time. If the sequencer were to "hang up" and thereby fail to open the ground to the coil of the relay, the consequence would be non-operation of the MS logic. However, with the 20-second timer, the relay deenergizes, opening B+ to the relay coil. Protection is given also against the failure of the 20-second timer to stop by the opening of the relay after the 14-second operation of the sequencer.

*A 1-inch cube supplied by Matrix Research and Development, Nashua, New Hampshire

(1) Calibrator Electronics (Figures 29 and 30)

Diodes D1 and D3 constitute an AND gate (Figure 31). With 13.95 volts applied to R3, D1 and D3 are conducting through the current paths of R2 and R13 respectively. With the actuation of cam 6, D3 is back-biased, but because of the conduction of D1 the voltage at D2 remains at 0.6 volt. D3 is back-biased for the duration time of cam 6 (120 - 190 seconds). A 2-second gate pulse from the MS logic is coupled to the emitter-follower Q1 whose output back-biased D1, allowing the trigger line into D2 to go positive. This trigger turns on the sequencer circuitry as well as the 20-second timer. The battery gate Q2 is latched ON, delivering B+ to the unijunction oscillator Q3 and saturating the transistor switch Q4, which supplies B+ to the relay RL1. The emitter of the unijunction starts rising at the RC rate of R7-C4 until the breakdown voltage of approximately 4 volts is reached. The positive output pulse at R9 is ac-coupled to the base of Q5. The saturation of Q5 resets or turns off the battery gate Q2, thus stopping the oscillator and turning Q4 off, deenergizing B+ to RL1.

(2) Sequencer Electronics (Figures 32 and 33)

The sequencer electronics for the mass spectrometers consists of a 2-second oscillator and a seven-stage shift register, each stage driving a relay which switches the calibrating voltage to the feedback loop of the electrometer.

The coincident pulse derived from the AND gate circuitry on the calibrator electronics card is coupled to the emitter-follower Q6. The output of Q6 triggers the SCR Q11 to the ON mode. The conduction of Q11 supplies a voltage at its emitter which supplies B+ to the unijunction oscillator Q2 and drives Q5 to saturation. The saturation of Q5 supplies a ground path for RL1, as explained previously. The oscillator-emitter rises to breakdown at the RC rate of R8 - C10 to generate positive pulses at 4 volts amplitude every 2 seconds. The pulses, delivered to the trigger input line of the shift register, advance the cascaded stages until the firing of Q13 occurs. The pulse derived from the conduction of Q13 is ac-coupled to the base of Q7. The conduction of Q7 resets Q11, thereby stopping the oscillator and turning off Q5 which opens the ground to the relay RL1.

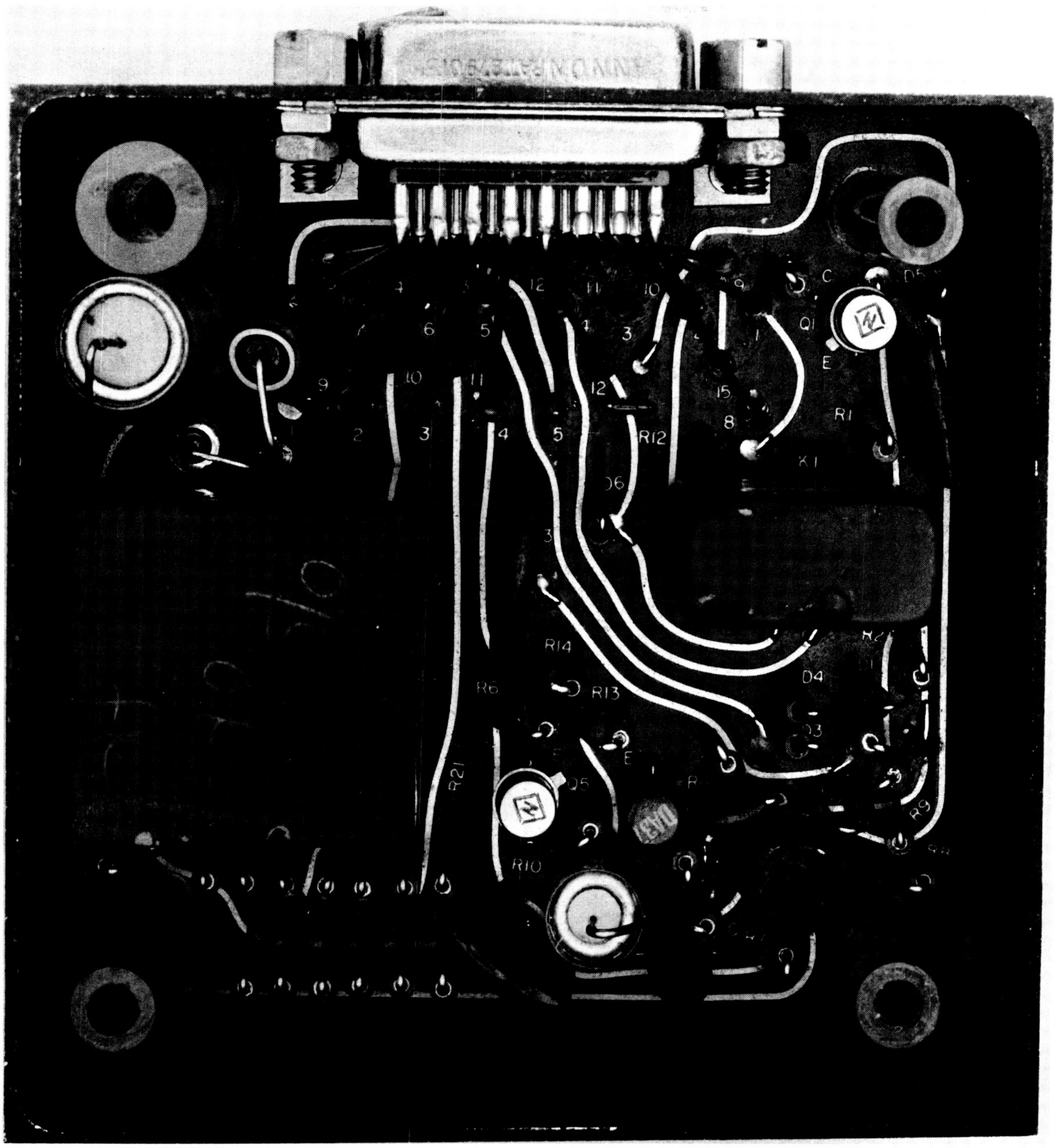


Figure 29–Mass Spectrometer Calibrator, Top View

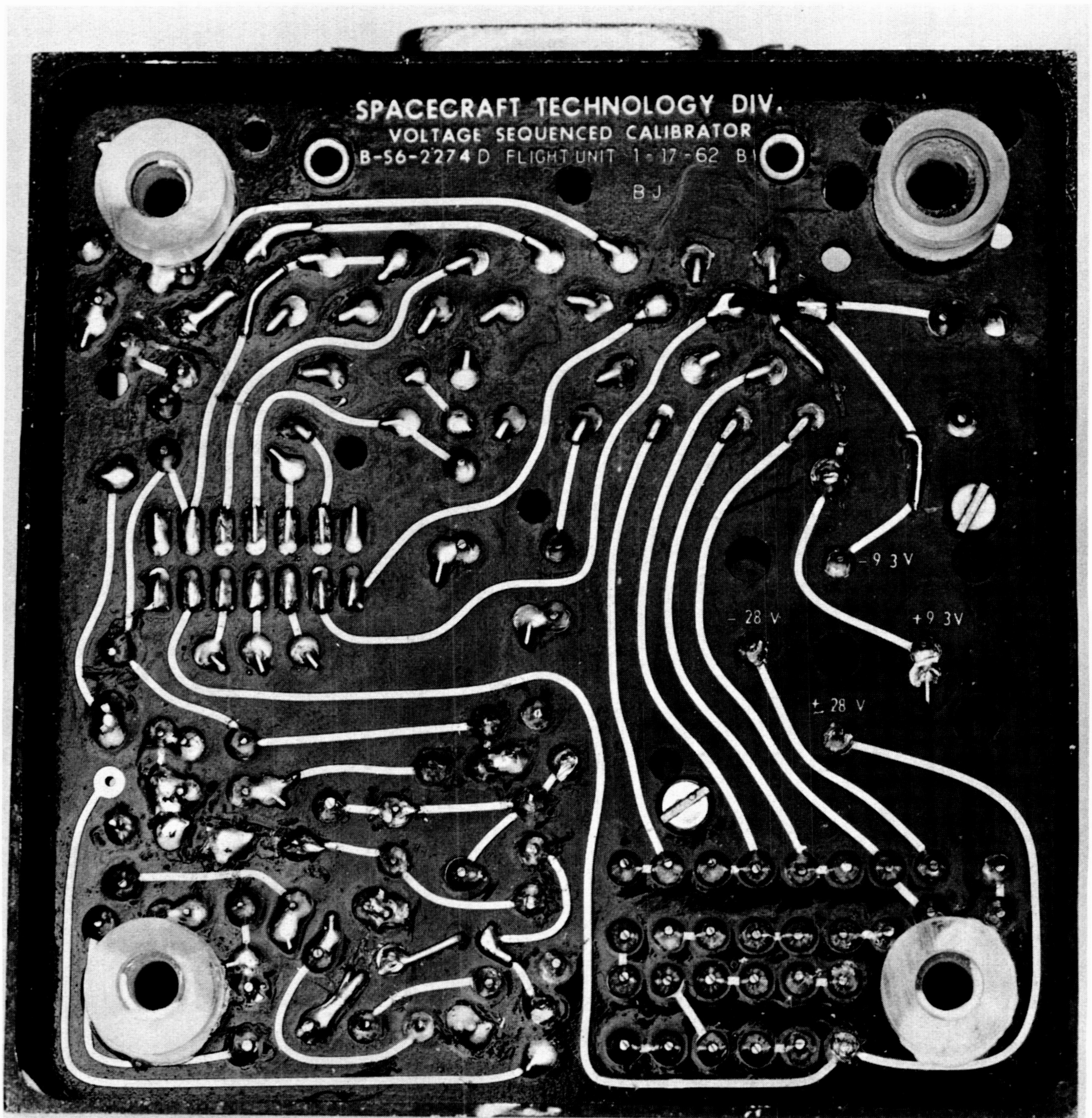


Figure 30-Mass Spectrometer Calibrator, Bottom View

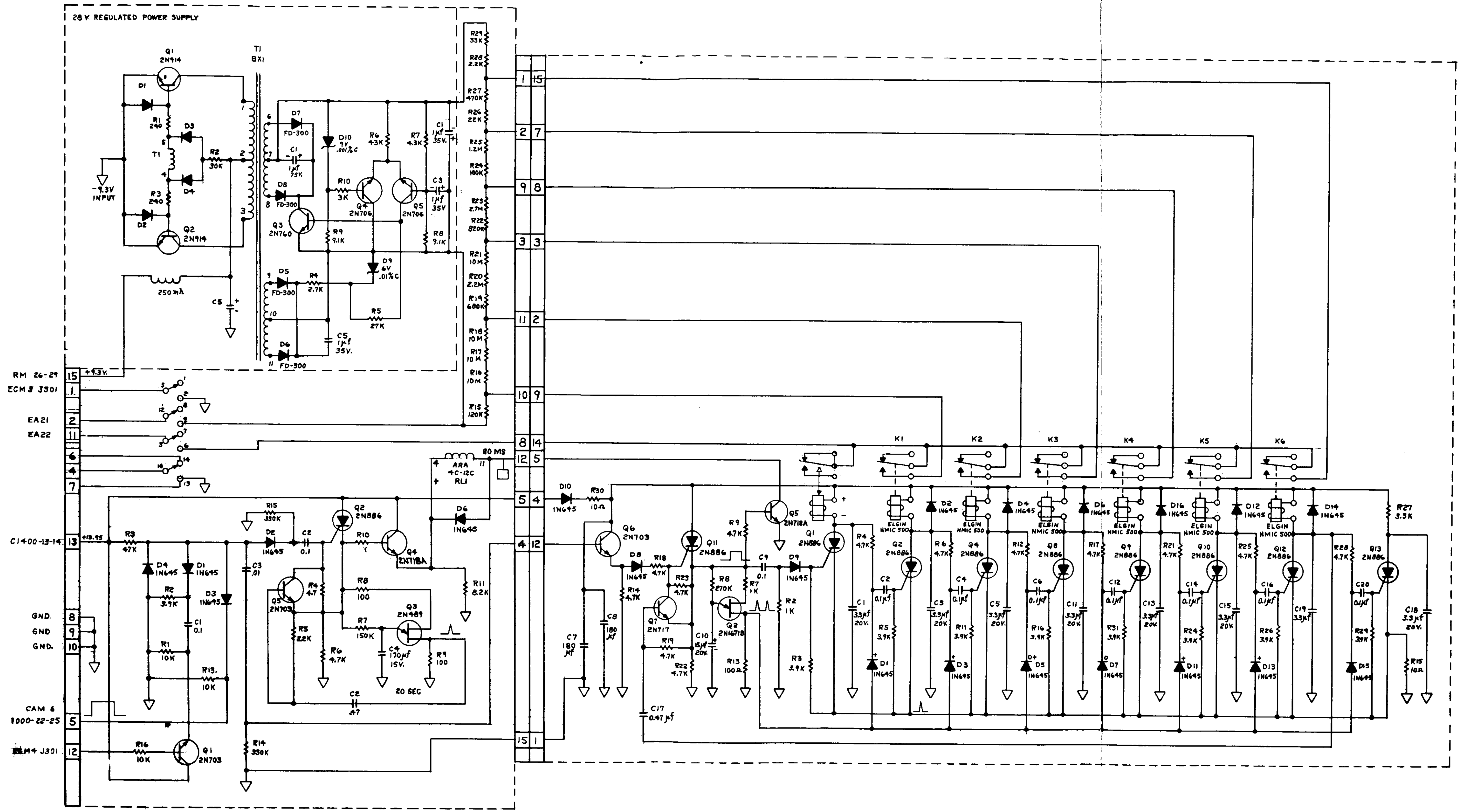


Figure 31–Mass Spectrometer Calibrator Sequencer, Schematic Diagram

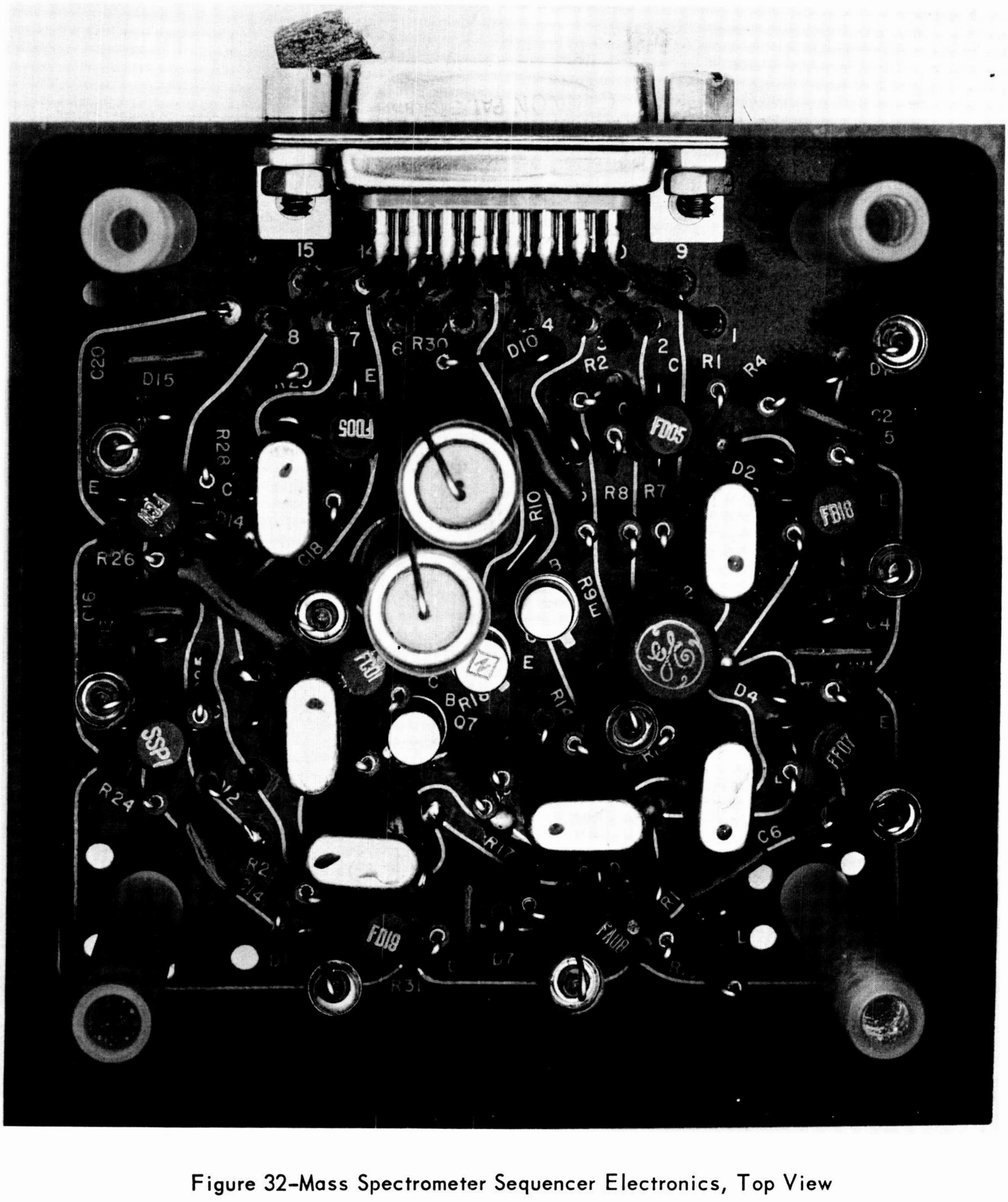


Figure 32–Mass Spectrometer Sequencer Electronics, Top View

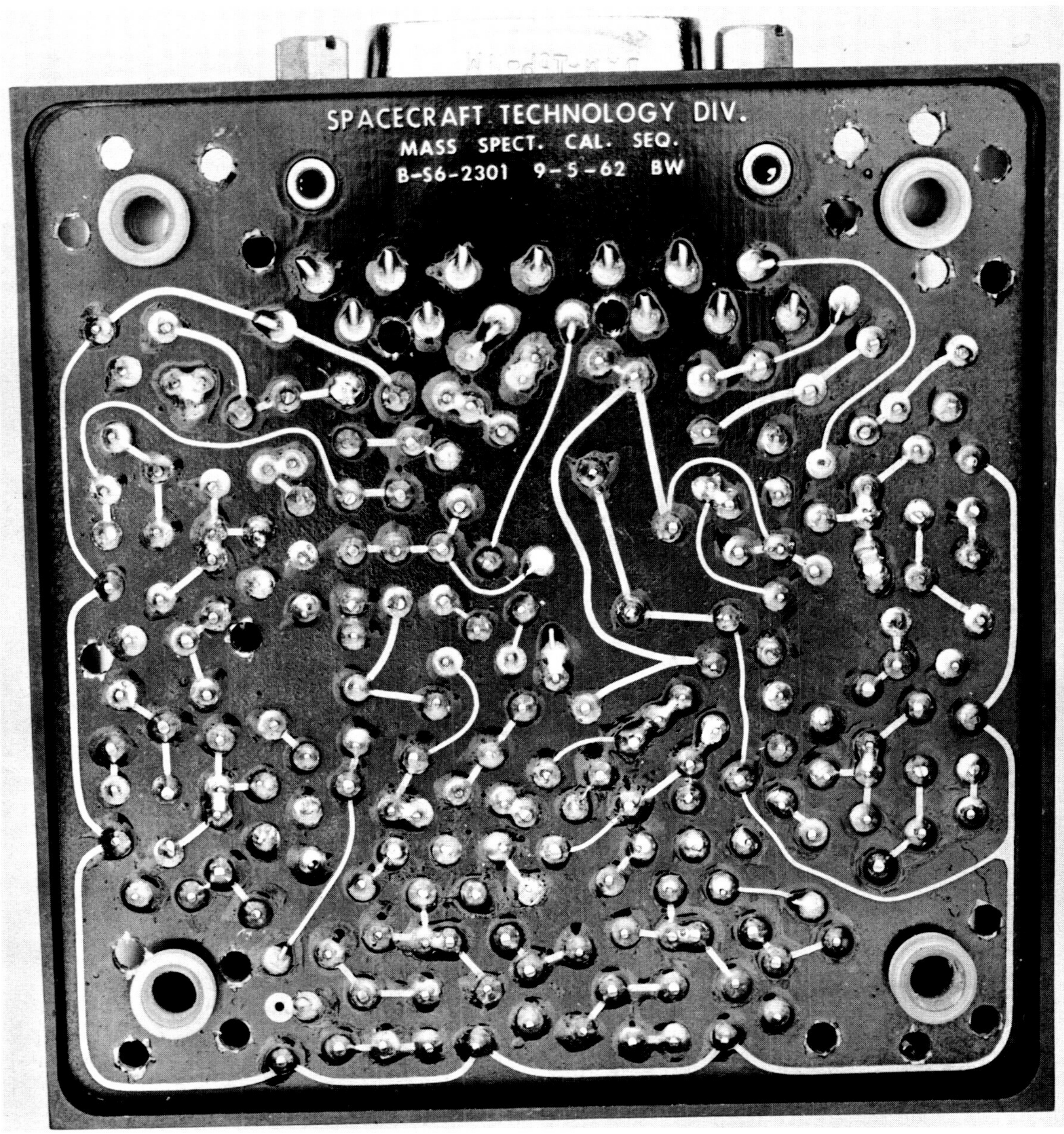


Figure 33–Mass Spectrometer Sequencer Electronics, Bottom View

The turn-on of Q11 also turns on Q1 which readies or presets the shift register. This preset reduces the positive voltage on the cathode of D1 to approximately 0.6 volts. Because of the OFF condition of Q2 through Q13, all the base diodes have a positive voltage on their respective cathodes. D1, which is therefore receptive to the first positive pulse from the oscillator, couples the first pulse to the base of Q2. The conduction of Q2 closes the relay RL1, placing the first calibration step (0.01 volts) on the RL1 relay contacts. The latching of Q2 generates a positive pulse on the common emitter line of all the stages, which turns Q1 off. Diode D3 is now ready to receive the next pulse from the oscillator (2 seconds later). Q4 latches, Q2 is turned off, and D5 is readied for the next pulse initiation. Turn-on and-off is sequenced down the line until Q13 is turned ON. The turn-off of Q12 generates a positive going pulse to the base of Q7, the reset transistor; Q7 therefore resets the battery gate Q11, which in turn stops the oscillator, and the 14-second calibration is completed.

V. SUMMARY

At the time of this writing, Explorer XVII has been performing properly for 2 months. The payload has been commanded ON more than 400 times. All programmer functions have worked or are working properly.

The authors wish to express their gratitude to the many people of the Spacecraft Technology Division who assisted in the fabrication of the payload electronics, and especially to V. L. Arillo of this Section who participated in the many test phases during development.

APPENDIX

A. Nutation Damper Timer (C1400) (Figures 1A and 2A)

A redundant timer system for releasing the nutation damper mechanism 1800 seconds after launch was designed and fabricated for the Explorer XVII payload. Because of the addition of the squib-grounding circuitry, these electronic timers were replaced with conventional G-switches; however, the circuit description will be included in this appendix.

As seen in Figure 3A, the actuation of the G-switch causes a voltage rise at R36. This rise is differentiated by C8 and coupled to the battery gate SCR (Q7) by D10 and R38. The turn-on of Q7 drives Q10 to conduction (which supplies Q8 with B+). Q8 is a unijunction transistor used as a relaxation oscillator to generate pulses at the RC rate of R56, R29, R30, R31 and C6. The pulse rate is therefore one pulse every 1.8 seconds. The output pulses at B1 of Q8 are coupled to the gate of Q12 by the coupling condenser C9. Q12 is a pulse generator which, when turned on, dumps the voltage stored on C11 into the load R51. These pulses drive the Incremag decade counter, which counts by 1000 to give a total elapsed time of 1800 seconds before an output pulse is delivered to the gate of Q11. This pulse amplifier dumps C12 into the emitter load R50. This pulse is used to fire the squibs which release the nutation damper, and to gate Q9 on for the pulse duration. The turn-on of Q9 returns Q7 to the OFF condition, which shuts down the oscillator.

Two timers are incorporated for redundancy. Their outputs are connected in parallel for actuation of the squib-firing circuitry.

Q13 is the reset amplifier which dumps C13 into the load R48 when its gate is pulsed by the turn-on of Q7. The pulse output from Q13 drives the reset line of the core counter which saturates all the cores to zero count. It is inherent in the application of the decade counter that an output pulse is delivered when resetting the cores; this pulse must be prevented from turning Q11 ON. Q15, therefore, has the function of damping or grounding the gate-signal lead of Q11 during the clock turn-on or reset time.

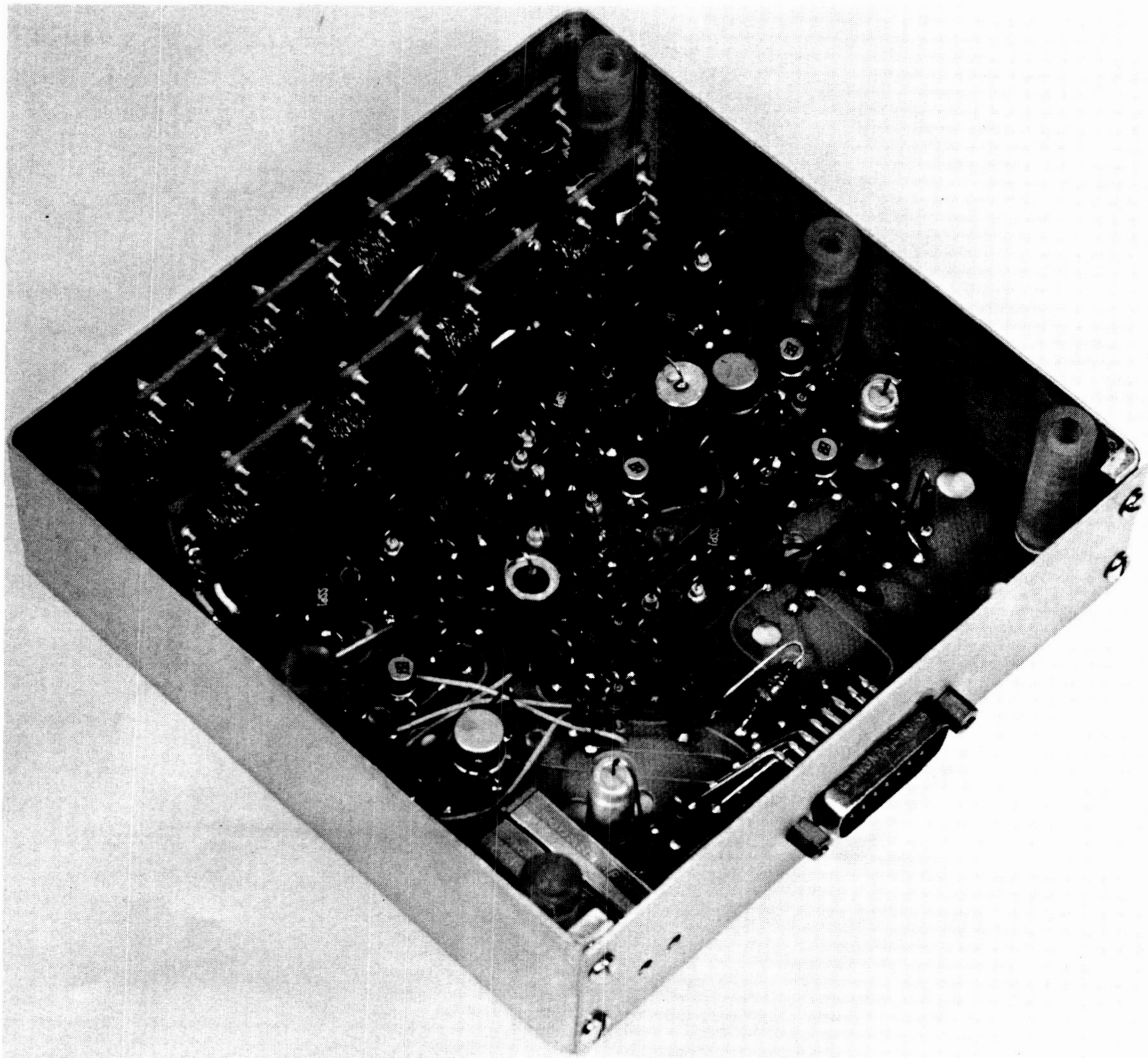


Figure 1A-Nutation Damper Timer, Top View

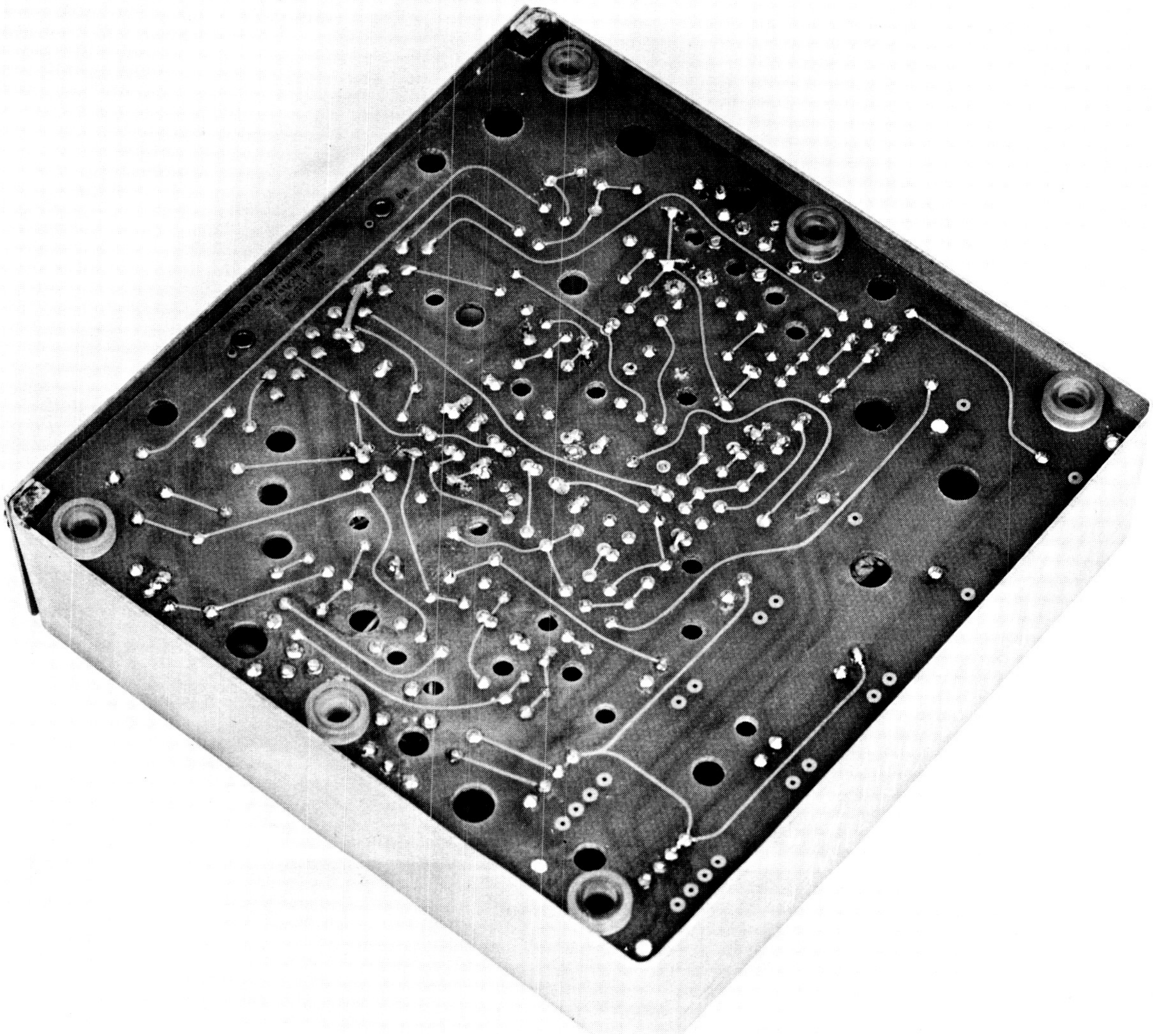


Figure 2A–Nutation Damper Timer, Bottom View

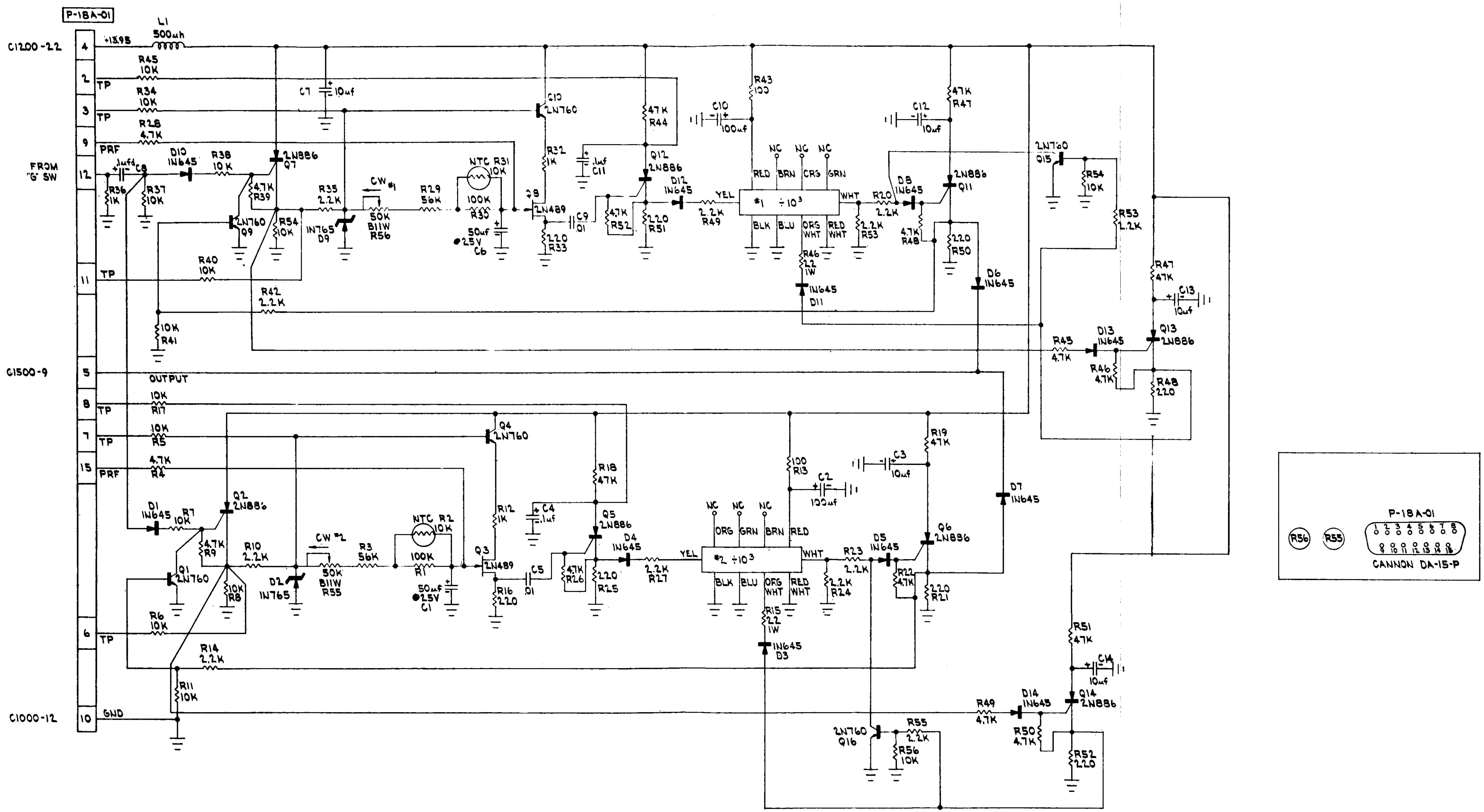


Figure 3A-Nutation Damper Timer, Schematic Diagram

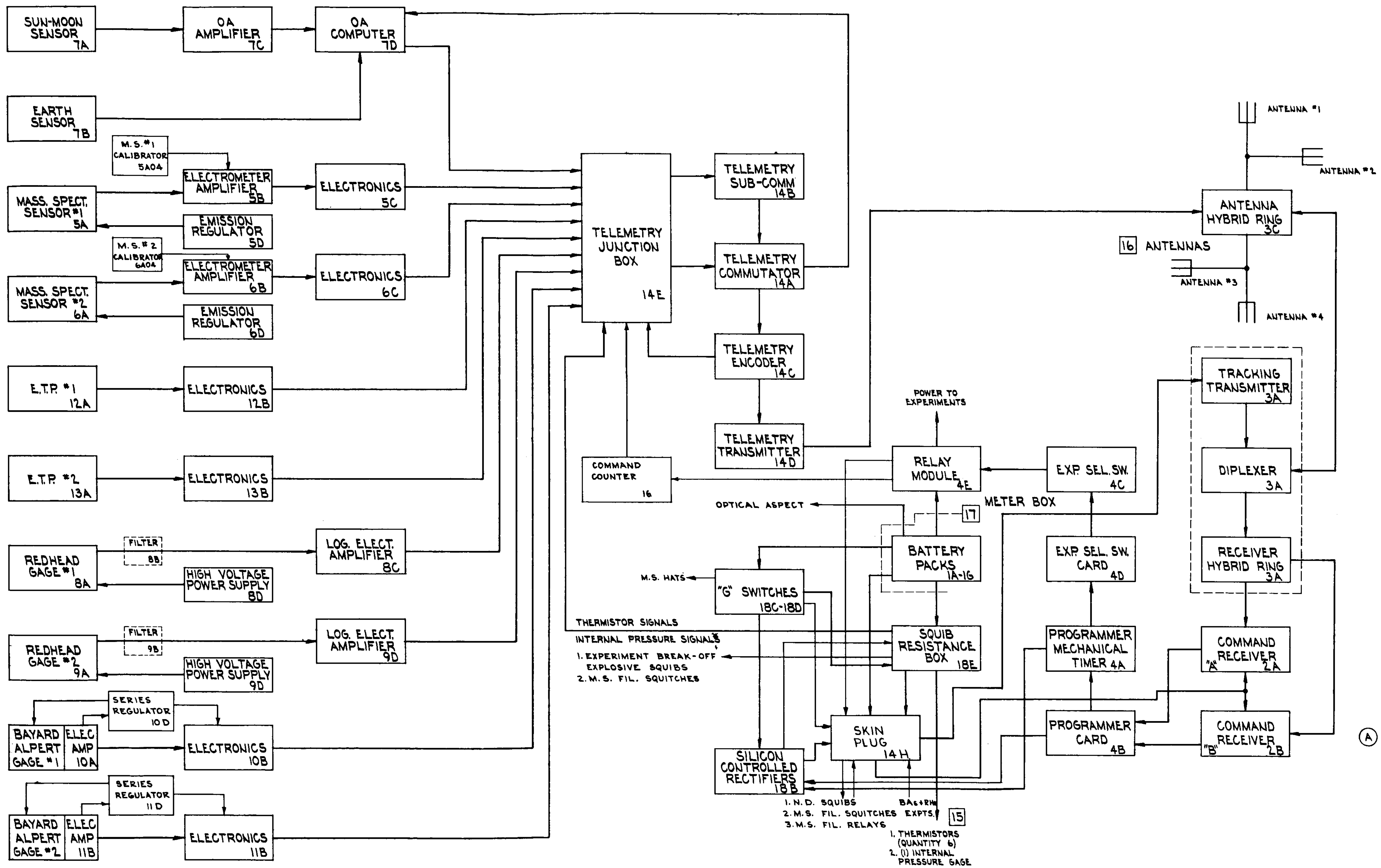


Figure 4A-Spacecraft Electronics, Block Diagram

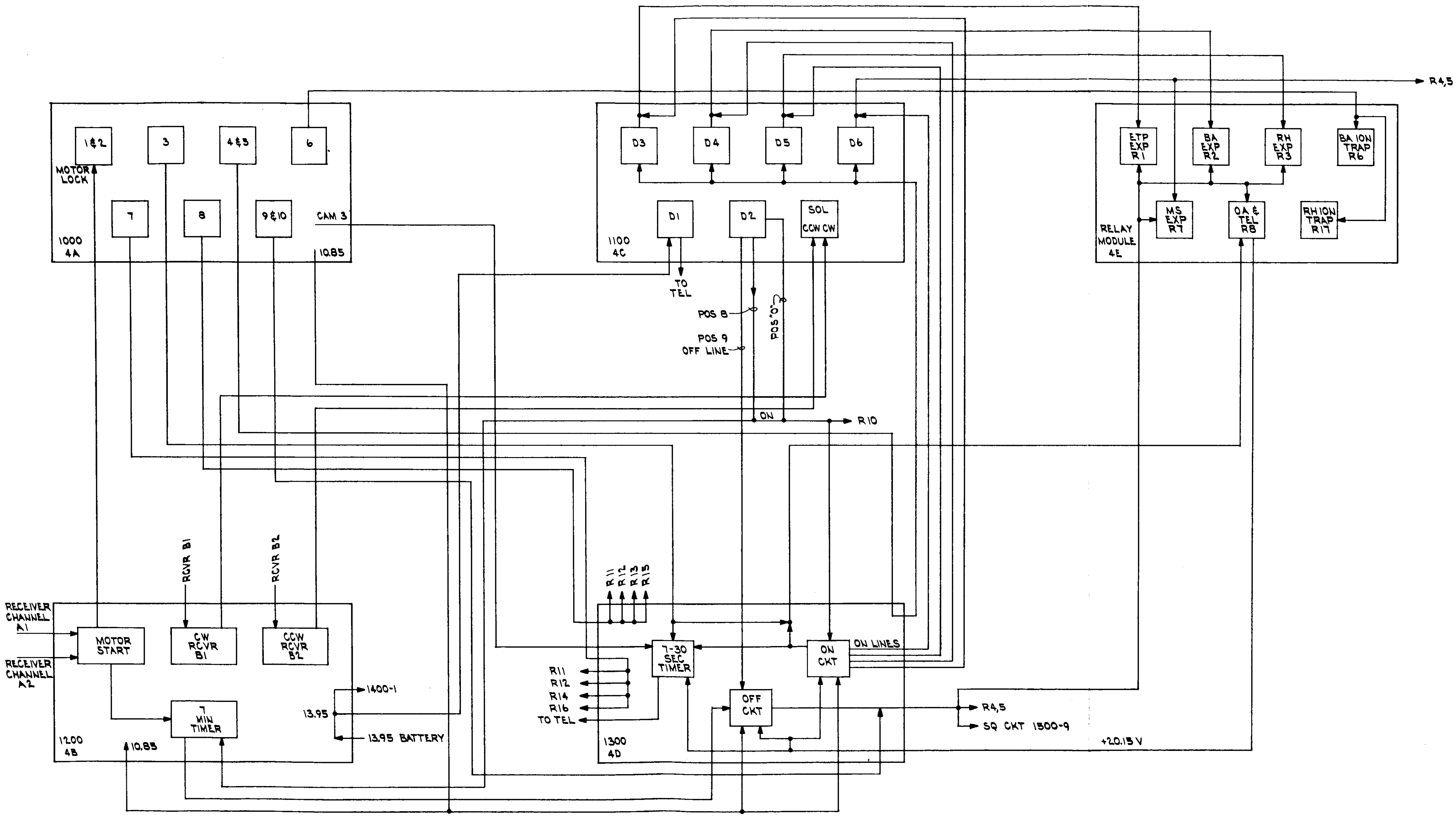


Figure 5A-Programmer, Block Diagram

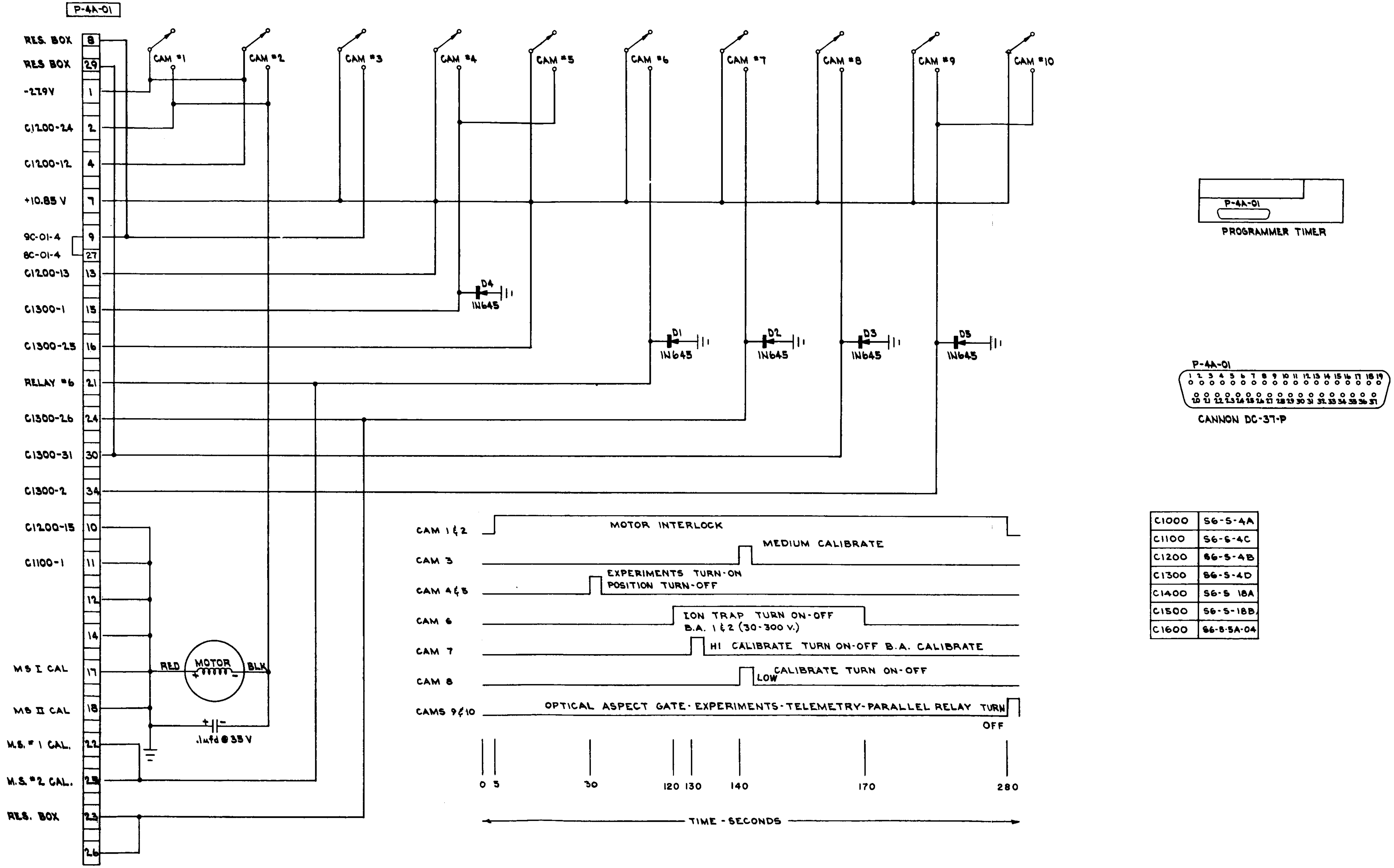


Figure 6A–Programmer Timer, Schematic Diagram

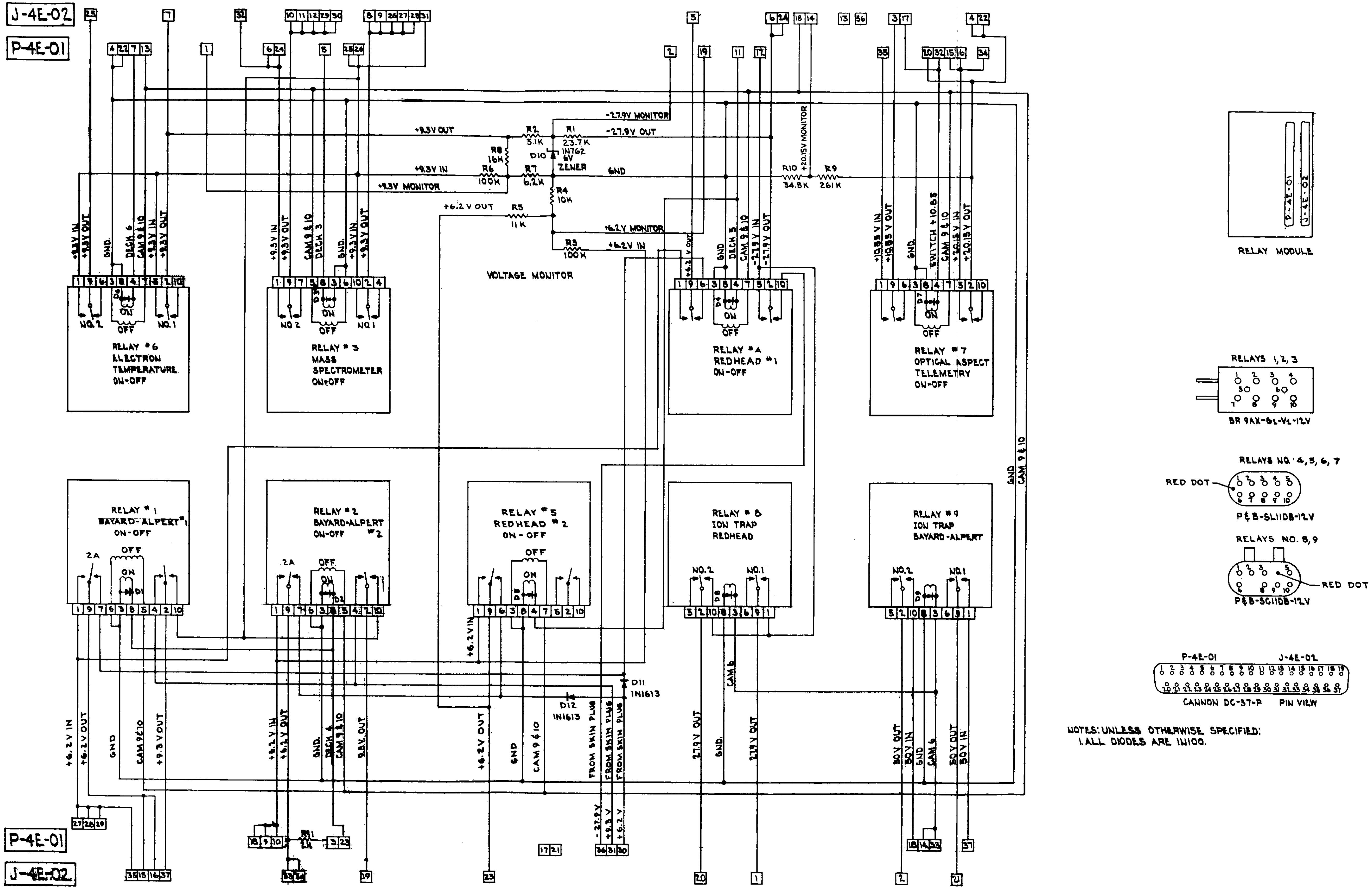
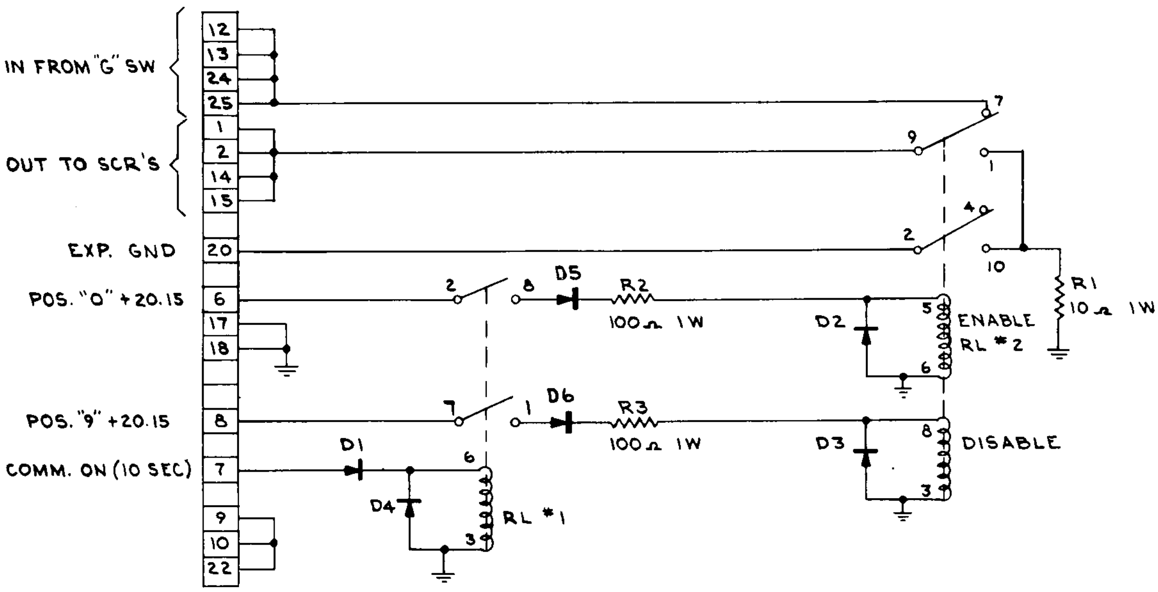


Figure 7A–Relay Module, Schematic Diagram



NOTES:

1. RELAY #1 P+B SC11D
   RELAY #2 BABCOCK BR9AX-G3-V2
2. ALL DIODES 1N645

Figure 8A-Squib Circuit Grounding, Schematic Diagram

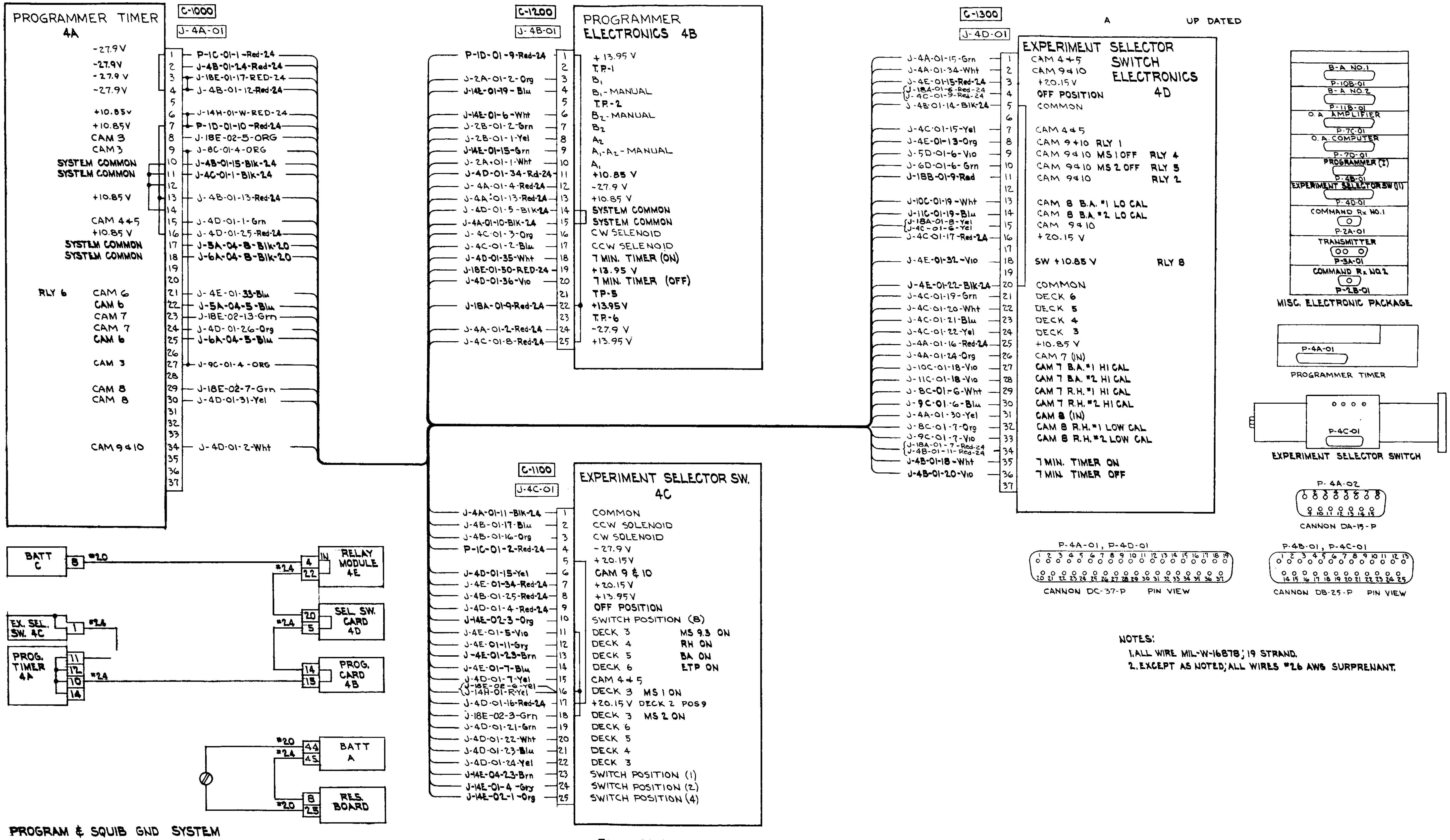


Figure 9A–Programmer, Cable Diagram